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THE FORT SILL
FIRE SUPPRESSION SYMPOSIUM
REPORT

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THE FORT SILL
FIRE SUPPRESSION SYMPOSIUM
REPORT

(12) 272

(24-25 July 1979)

Prepared By
Directorate of Combat Developments
USA Field Artillery School
Fort Sill, Oklahoma 73503
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SECTION I: FOREWORD

On 24 and 25 July 1979 a Fire Suppression Symposium hosted by the Directorate of Combat Developments (USAFAS) was held at Fort Sill. The purpose of the symposium was to arrive at a unified approach for studying the suppressive effects of fires on the modern battlefield. A total of 50 individuals participated in the five work groups with approximately 40 members from the civilian and military analytical community outside of Fort Sill.

The symposium was divided into three sessions, with the first session being devoted to presentations by six participants. (The sixth presentation was made during the evening of the first day.) At the conclusion of the first session the participants arrived at a consensus definition of "suppression." It was "Suppression is the process of temporarily degrading unit or individual combat performance through psychological and physical means." The symposium members also decided that within the framework of the definition the focus of the work groups would be on the direct fire and indirect fire aspects of suppression. Electronic warfare, psychological operations, and obscuration were considered, but it was decided that because of the limited amount of time allotted, the discussion of them would be deferred.

In the second session participants worked in their five work groups centering attention on their specific subject areas* as shown in the table of contents (Section V). The second session terminated group activities for the first day of the symposium. Reports on the proceedings of each group were collected and reproduced.

At the beginning of the third session the participants received a reproduced copy of the proceedings of each group's effort up to that point. In this manner "cross-fertilization" between groups was effected. Again the participants met in their respective groups, finalized their work, and adjourned to the Combined Arms Room where each work group leader presented a summary of his group's effort.

In addition, there were other materials submitted, but not presented at the symposium. These materials are included in Section VI of this report.

* (Suppression variables (effects);
Suppression variables (causes);
Data Base Requirements;
Suppression Modeling;
Suppression/Countersuppression combat and training developments).

SECTION II: FIRE SUPPRESSION SYMPOSIUM

SCHEDULE

Fort Sill, Oklahoma

24 July

0800-0830	Inprocessing	
0840-0850	Opening Remarks	MG Jack N. Merritt CAR, Room 115, Snow Hall
0900-0930	"Methodology for Quantifying Suppressive Effects of Artillery"	Mr. Landry, SPC
0930-1000	"Suppression in the TRADOC"	Mr. Roger Willis, TRASANA
1000-1030	Coffee Break	
1030-1100	"Suppression Testing"	Dr. Marion Bryson, CDEC
1100-1130	"Suppression Modeling w/Data from Yom Kippur War"	Mr. Paul Kunselman, AMSAA
1130-1200	"SEAD"	LTC Redding, USAF
1200-1330	Lunch	
1330-1630	Working Groups	
1900-2100	Dinner "Human Behavior in Combat"	COL Trevor Dupuy

25 July

0800-1000	Working Groups	
1000-1030	Coffee Break	
1030-1200	Summary of Work Groups	Combined Arms Room, Room 115, Snow Hall

SECTION III: FIRST SESSION-PRESENTATIONS

Note: In order to stimulate the thoughts of the participants, six of them were asked to present the results of their study of suppression. For the first four speeches only the paper copies of the transparencies used were provided by the speakers; however, transcripts of the last two speeches were made available. The titles of the speeches along with the names of the speakers appear below in the order in which they were presented.

A. "Methodology for Quantifying Suppressive Effects of Artillery" - Mr. Clifford J. Landry, Director, Land Systems Division, Systems Planning Corporation.

B. "Suppression in the TRADOC" - Mr. Roger Willis, Operations Research Analyst, Chief Phenomenology and Model Processes Branch (TRASANA).

C. "Suppression Testing" - Dr. Marion Bryson, Scientific Advisor, HQ, USACDEC.

D. "Suppression Modeling w/Data from Yom Kippur War" - Mr. Paul Kunselman, Physicist with Tactical Operations Office, AMSAA.

E. "Suppression of Enemy Air Defense (SEAD)" - LTC Kenneth Redding, United States Air Force Representative at Fort Sill, Oklahoma.

F. "Human Behavior in Combat" - COL (Ret) Trevor N. Dupuy, Noted Author, President, T.N. Dupuy Associates.

A. "Methodology for Quantifying Suppressive Effects of Artillery" - Mr. Clifford J. Landry, Director, Land Systems Division, Systems Planning Corporation.

Methodology for Quantifying Suppressive Effects of Artillery

BACKGROUND

- NTA study *Effect of Soviet Artillery Fire Support on U.S. Infantry AT and Artillery CF Capabilities,* Apr 77
- In addition to P_k calculations, wanted to quantify suppressive effects
- Developed methodology
- Used available test and historical combat data
- Made judgments
- Calculated total effects
- MOE was mission availability

DEFINITION

Suppression: A temporary degradation in combat effectiveness due to the terminal effects of explosive munitions

CAUSED BY

- Hitting the ground
- Movement to protective bunker
- Minor wounds
- Light damage
- Shock or trauma
- Neuropsychiatric disorder

HITTING THE GROUND

- CDEC Suppression Experiment, Phase II – 1976 (SUPEX II)
- • Fraction of ATGM gunners interrupted (Ps) as a function of weapon caliber and miss distance (R)
  • Duration of effect estimated to be 10 sec
- Least square fit of data to

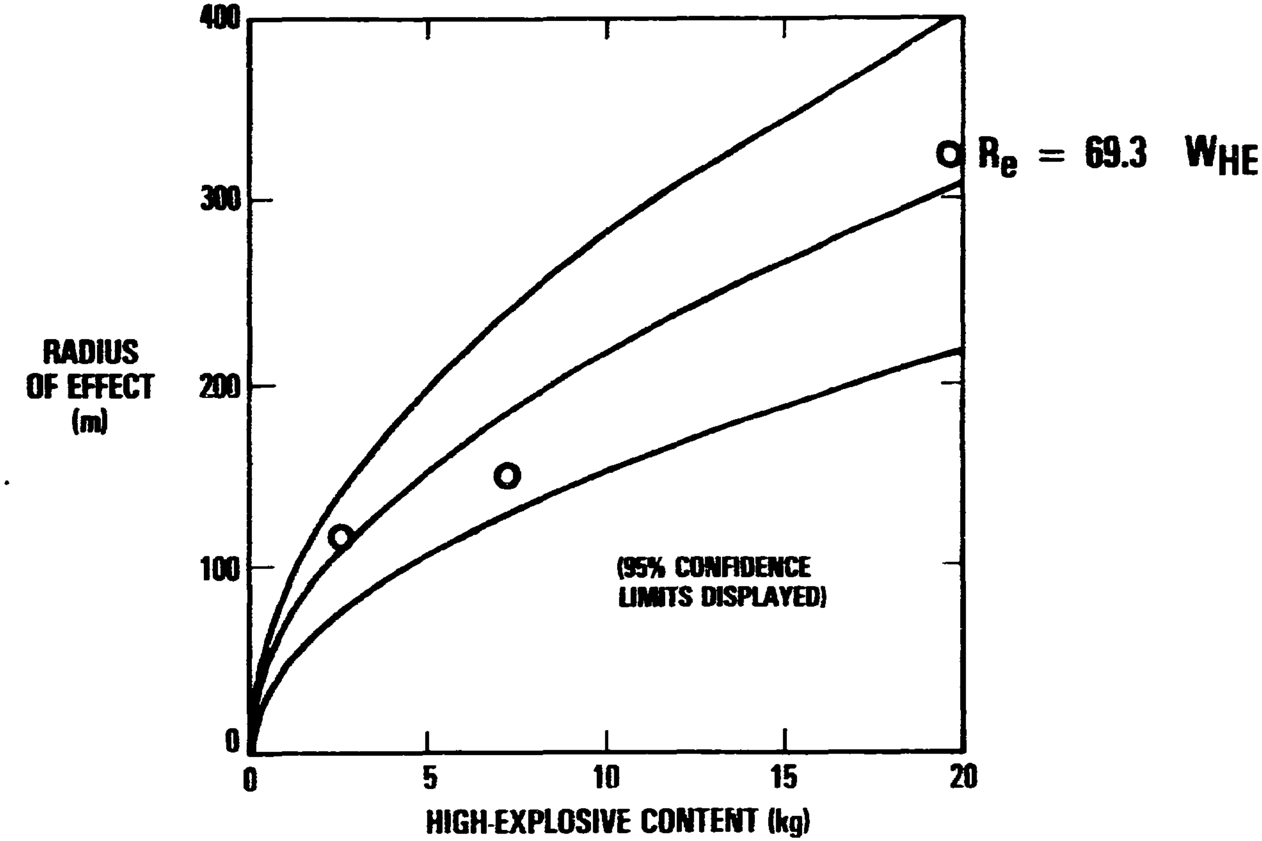
$$P(s) = \exp - \left(\frac{R}{R_e}\right)^2$$

- Least square fit of values for R_e to

$$R_e = K(W_{HE})^{1/2}$$

R_e = mean effective radius
W_{HE} = HE weight of round

SUPPRESSION RADIUS AS FUNCTION OF PROJECTILE HIGH-EXPLOSIVE CONTENT

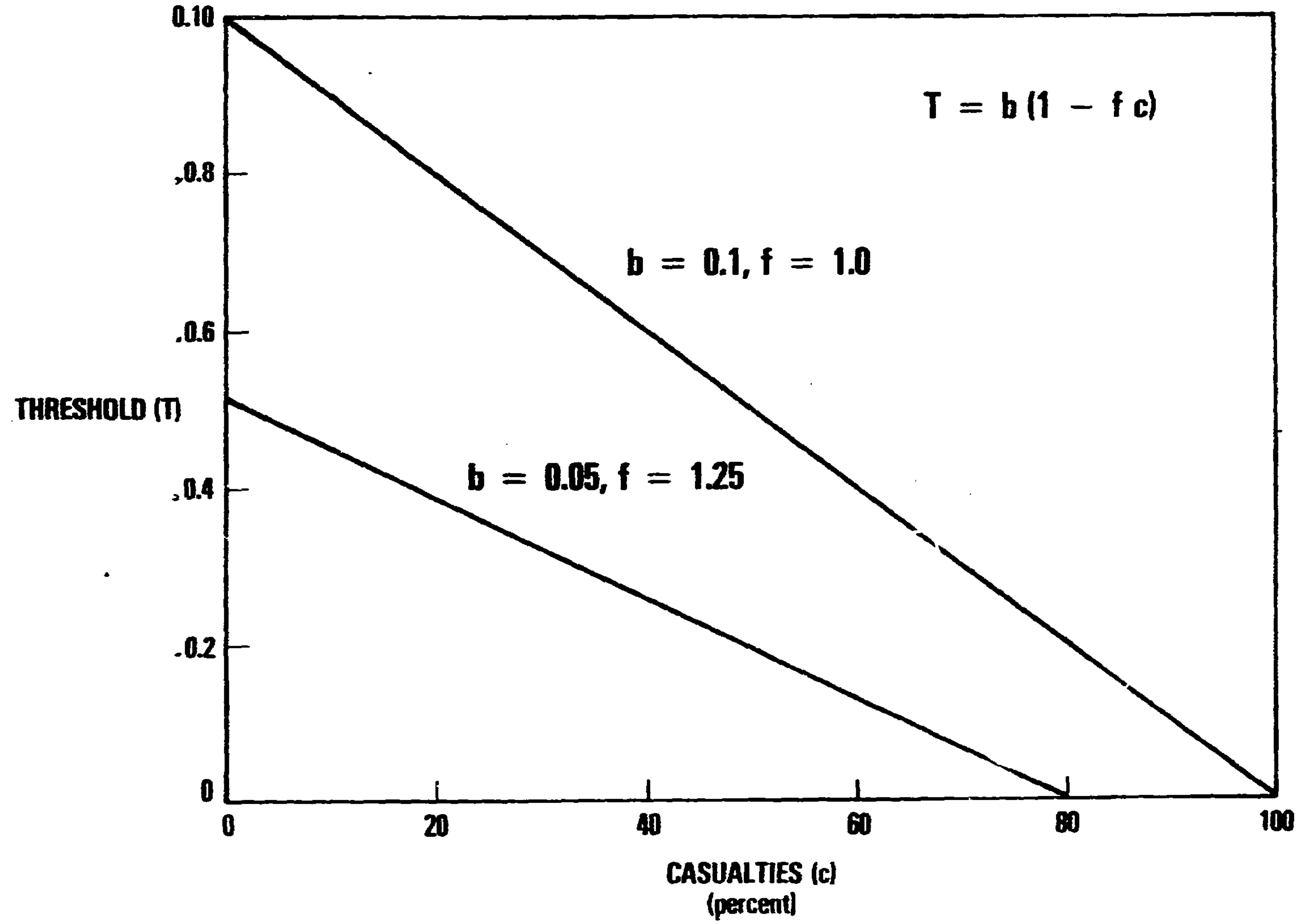


MOVEMENT TO PROTECTIVE BUNKER

- Threshold (T) is dependent upon acceptable casualty rate (b) adjusted by total casualties (c)
- $T = b(1 - fc)$ where f is a casualty weighting factor
- Delays for resuming fire estimated to be on order of 30- to 100 sec for ATGM and AT crews*
- Longer delays expected for towed artillery batteries – up to 5 min

*Soviet armed forces magazine, *Military Herald*

EXAMPLES OF THRESHOLD FOR MOVEMENT TO PROTECTED BUNKER

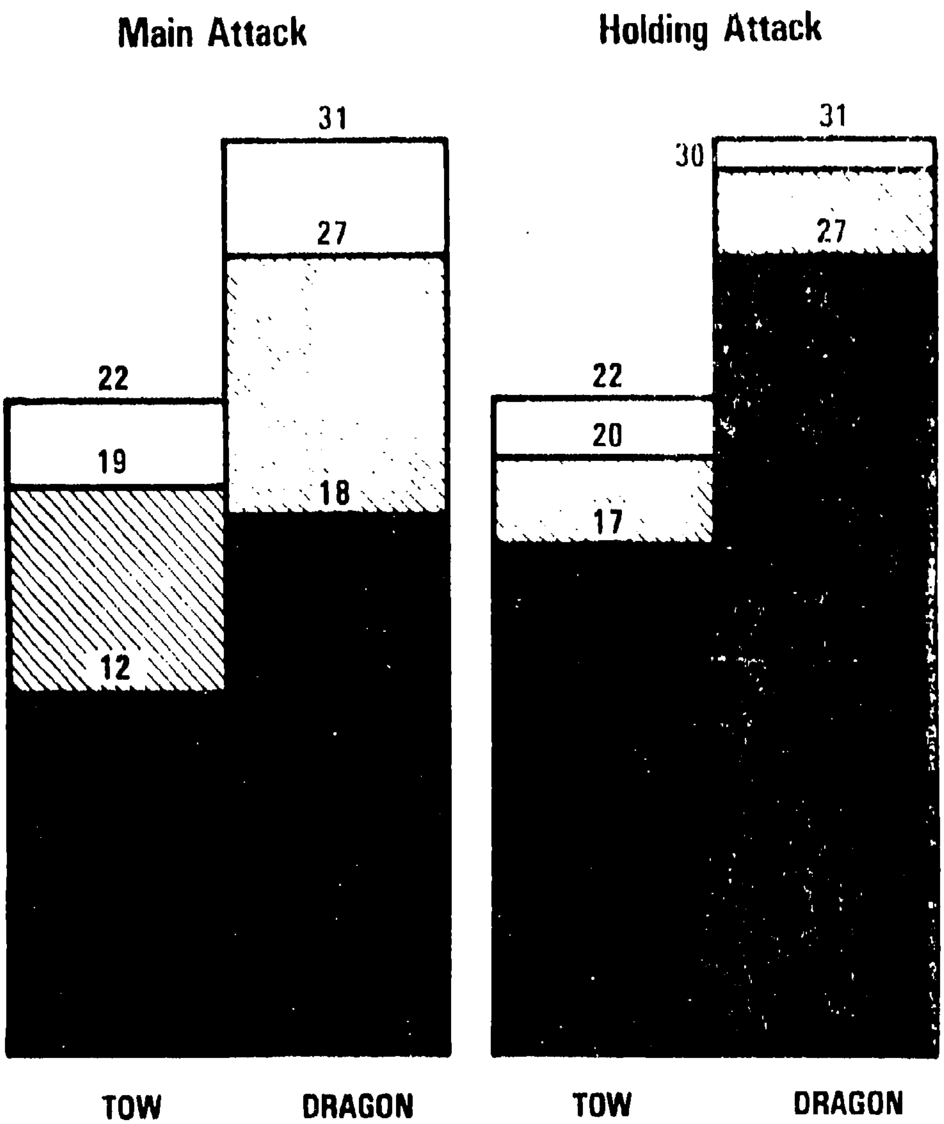


COMPOUND EFFECTS
(MINOR WOUNDS, LIGHT DAMAGE, SHOCK OR TRAUMA, NEUROPSYCHIATRIC DISORDERS)

- British attacker casualties drastically reduced for attacks within 15 or 30 min of heavy artillery prep
- Fraction of defenders affected (F) = 0.8 - 0.9
- Soviet neutralization fire, similar effect for 20 min
- Representative neutralization densities (D) for Soviet weapons
  - 10 - 20 rounds per hectare for troops in open
  - 100 - 150 rounds per hectare for troops in APCs
- From $F = 1 - e^{-D(MAE)}$ equivalent suppressive areas are approximately
  - 1000 - 2000 m^2 for troops in open
  - 120 - 140 m^2 for troops in APCs
- Similar analysis with British data gives 300 - 500 m^2 for troops in emplacements

MAE = mean area of effectiveness

RESULTS OF SOVIET ARTILLERY FIRE
(AVERAGE NUMBER OF EFFECTIVE WEAPONS DURING ATTACK PHASE)



COUNTERFIRE MODEL

SPC MODEL

- DETERMINISTIC MODEL
- OUTPUT:
  DEGRADATION OF ARTILLERY DUE TO DAMAGE, CASUALTY AND SUPPRESSIVE EFFECTS OF COUNTERBATTERY FIRES IN A GIVEN SCENARIO
- INPUTS:
  - FIRE PLAN FOR SCENARIO
  - OUTPUT FROM SNOW QUICK MODEL

B. "Suppression in the TRADOC" -Mr. Roger Willis, Operations Research Analyst, Chief of Phenomenology and Model Processes Branch (TRASANA)

SUPPRESSION IN TRADOC MODELS

1. FOURCE
2. DIVWAG
3. DBM
4. JIFFY
5. AFSM (LEGAL MIX)
6. STAR
7. CARMONETTE
8. DYNTACS
9. TRACOM, BLDM
10. ASARS
11. BATTLE

	MODEL									
	AMSWAG AIDM	ASARS	BLDM	BONDER/ IUA AIR CA 5	CARMON-ETTE	DIVLEV	DIVWAG	DYNTACS	DIFFY	LEGAL MIX
NO. OF SUPPRESSED STATES	2	6	2	2	3?	2	2	2	2	2
ACTIVITIES SUPPRESSED										
FIRE	YES	YES	YES	YES	YES		NOT DIRECT	YES	YES	YES
MOVE	NO	YES	NO	NO	YES		YES	NO	NO	NO
OBSERVE	NO	YES	YES	YES	YES		NO	YES	NO	NO
COMMUNICATE	NO	NO		NO	?		NO	FDC	NO	NO
COUNTERPRODUCTIVE EFFECTS	?	?	NO?	NO?	YES		NO	NO	NO	NO
DURATION OF SUPPRESSION	EXP. STOCH?	STOCH	STOCH	MATRIX INPUT	?		MATRIX INPUT	MATRIX INPUT	?	EXP.?
CONDITIONS										
TYPE OF ROUND			3	3	X		3	4?	NO	
NO. OF ROUNDS					X		X	X	NO	
TARGET TYPE			X	X	4		5	5?	4?	
TYPE OF ENGMT									X	
ATKR OR DEFNDR									2	
FORCE RATIO									X	
MISS DISTANCE		?			GROSS		NO	?	NO	
TARGET COVER			3	3						
NON-LETHAL HITS		?	X					X		
KILL PROB.	X	X								X
HUMAN FACTORS	X									X
ELEMENTS NOT SUPPRESSED	ARTY	ARTY	ARTY	ARTY			MNVR		?	

FOURCE SUPPRESSION

CAUSE: ARTILLERY

MANEUVER UNIT SUPPRESSED

  MOVEMENT: 30% TO 65%

  FIRING: FRACTION OF WEAPONS

ARTILLERY UNIT SUPPRESSED

  MOVEMENT: 30% TO 65%

  FIRING: STOP FOR 15 MINS.

SUPPRESSION DATA

WEAPON	CARMONETTE INPUTS (NEUTRALIZATION WT. PER RD)	CDEC (50% PROBABILITY SUPPRESSION AREA* PER ROUND)
8 INCH	14	6
155 MM	13	1
81 MM	11	0.70
105 MM (TANK)	11	0.80
50 CAL. MG (5 rds)	4	0.06

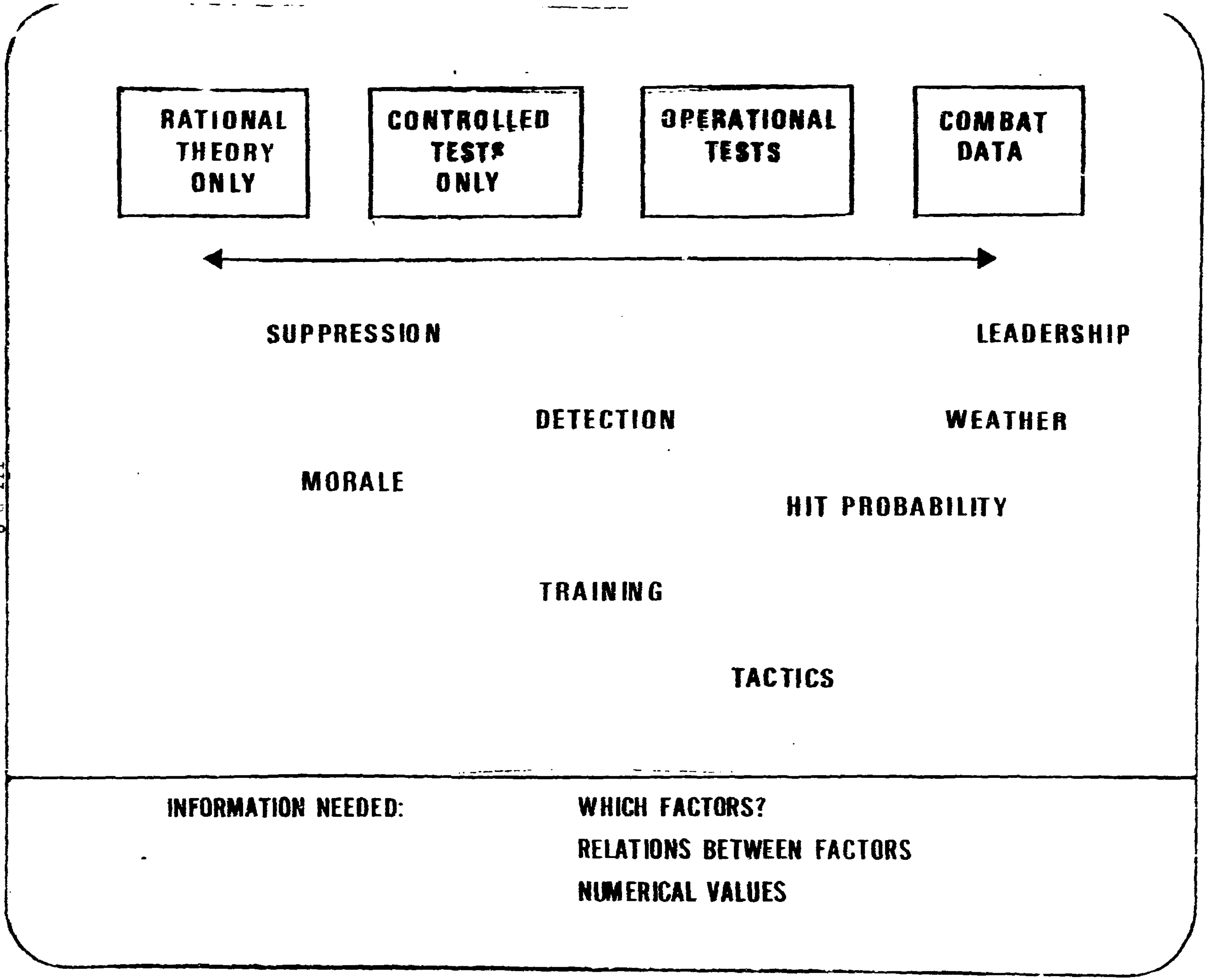
NORMALIZED: 35,300 M^2 = 1 FOR 155

CONDITIONS FOR SUPPRESSION

1. SPECIFIC WEAPON TYPE
2. NUMBER OF ROUNDS IMPACTING WITHIN VARIOUS DISTANCES DURING VARIOUS TIME INTERVALS.
3. TARGET TYPE (INCLUDING TANKS, ARTILLERY, AD, FORWARD OBSERVER, ETC.)
4. TARGET CONDITION, POSTURE AND EXPOSURE.

EFFECTS OF SUPPRESSION

1. MOVEMENT
2. OBSERVATION AND DETECTION
3. FIRING
   - AIMING
   - ACCURACY
   - RATE
   - PROBABILITY OF ABORT
4. COMMUNICATIONS
5. REDUCED DETECTABILITY
6. REDUCED VULNERABILITY


RATIONAL THEORY ONLY
CONTROLLED TESTS ONLY
OPERATIONAL TESTS
COMBAT DATA
SUPPRESSION
LEADERSHIP
DETECTION
WEATHER
MORALE
HIT PROBABILITY
TRAINING
TACTICS
INFORMATION NEEDED:
WHICH FACTORS?
RELATIONS BETWEEN FACTORS
NUMERICAL VALUES

CONCLUSIONS

1. REPRESENTATION OF SUPPRESSION IS IMPORTANT

2. MOST TRADOC MODELS INCLUDE SUPPRESSION

3. NO TWO MODELS DO IT ALIKE

   A. LOGIC
   B. INPUT DATA

4. IF ANY ONE IS RIGHT, THE REST ARE WRONG

5. OPERATIONAL TEST DATA BASE

   A. INADEQUATE

   B. IMPOSSIBLE?

C. "Suppression Testing" - Dr. Marion Bryson, Scientific Advisor, HQ, USACDEC

SLIDE #1

C D E C

S U P P R E S S I O N

E X P E R I M E N T A T I O N

SLIDE #2

TYPES OF SUPPRESSION

- REASONED SUPPRESSION
- UNREASONED SUPPRESSION
- PHYSICAL SUPPRESSION

SLIDE #3

DATA DESIRED

- PROXIMITY

→ 50%

→ 90%

- VOLUME

→ 50%

→ 90%

SLIDE #4

E X P E R I M E N T S

DUCS

DACTS

SASE

SUPEX I

SUPEX III

SLIDE #5

D U C S

- SIMULATED FIRE
- SOUND RECORDINGS
- TASK LOADING
- USE OF ACTUAL WEAPON

SLIDE #6

D A C T S

- LIVE FIRE
- PLAYERS WITH PERISCOPES
- CONCEALED AND OPEN
- ATTACH BY WEAPON SQUAD
- VARIABLE DISPERSION

SLIDE #7

S A S E

- LIVE FIRE
- RIFLES AND MACHINE GUNS
- STEREOTYPE SCENARIO
- CLOSE CONTROL OVER MISS DISTANCE
- IMPACTING AND OVERHEAD ROUNDS
- PATTERN AND VOLUME OF FIRE
- DAY AND NIGHT
- INDIVIDUAL AND UNIT SUPPRESSION
- COMBAT TRAINING

SLIDE #8

SUPEX I

- LIVE FIRE
- ALL WEAPONS FROM RIFLE TO 8 INCH
- SIMILAR TO SASE

SLIDE #9

SUPEX III

- INDIRECT FIRE ONLY

- EQUIVALENT CHARGE DETONATIONS

- ASPECT TO SUPPRESSEE

- SINGLE ROUND AND VOLLEY

SLIDE #10

MATHEMATICAL EQUATION

$$RMD = Ae^{BP(S)}$$

WHERE

RMD = RADIAL MISS DISTANCE

A,B = FITTED PARAMETERS

P(S) = PROBABILITY OF SUPPRESSION

e = 2.718

SLIDE #11

PROXIMITY REQUIRED FOR SUPPRESSION

(DIRECT FIRE)

WEAPON	P(S) = .5		P(S) = .9	
	DAR	SUPEX	DAR	SUPEX
M-3	3	1	0	0
M-16A1	3	1	0	0
M-2	24	26	5	8
M139	30	39	7	14
MK19	59	70	9	20

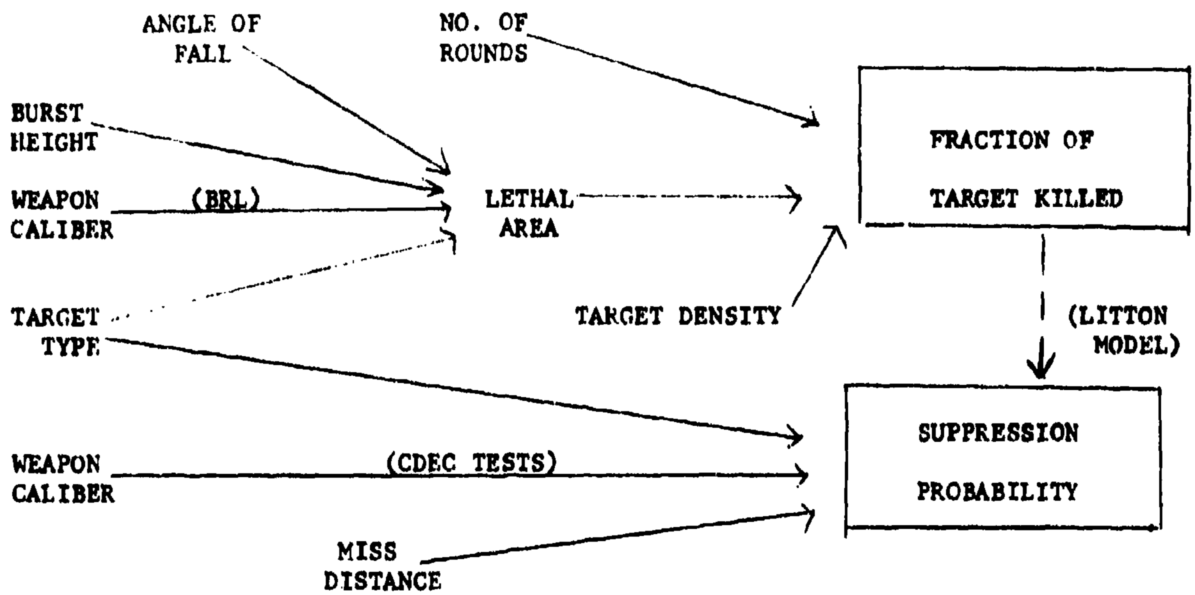
SLIDE #12

PROXIMITY REQUIRED FOR SUPPRESSION

(INDIRECT FIRE)

WEAPON	P(S) = .5			P(S) = .9		
	DAR	SUPEX	SUPEX III	DAR	SUPEX	SUPEX III
60MM	35	48	46	21	24	16
81MM	72	87	58	34	41	15
105 HOW	118	91	51	55	46	21
105 HEP-T	93	93		43	49	
2.75"	84	83		43	44	
155MM	144	106	104	77	72	63
8 IN.	392	257		169	126	

SLIDE #13


ANGLE OF FALL
NO. OF ROUNDS
BURST HEIGHT
WEAPON CALIBER
(BRL)
LETHAL AREA
FRACTION OF TARGET KILLED
TARGET TYPE
TARGET DENSITY
(LITTON MODEL)
SUPPRESSION PROBABILITY
WEAPON CALIBER
(CDEC TESTS)
MISS DISTANCE

CDEC SUPPRESSION EXPERIMENTATION

BY MARION R. BRYSON

ABSTRACT

During the years 1975 - 1978, the US Army Combat Developments Experimentation Command conducted a series of experiments to study the phenomenon of suppression. This paper describes briefly the experiments, the reports generated, and the availability of these reports.

1. <u>INTRODUCTION:</u>

Starting in 1975, USACDEC, Fort Ord, California, began a study of the effects of direct and indirect fire suppression. The purpose of this series of experiments was to evaluate what was called "reasoned suppression". Reasoned suppression was defined as that suppression resulting from a conscious decision by the suppressee to take cover because of perceived physical danger. This is as opposed to physical suppression (injury, death, obscuration) and unreasoned suppression (panic, fear, etc.). These experiments culminated in a series of reports. These reports are summarized in the following paragraphs. Following that is a brief comparison of the results of each of the report.

2. <u>SUMMARY OF REPORTS</u>:

a. Degradation Under Control Stimuli (DUCS), April 1975

(1) <u>Purpose</u>: This experiment was conducted to determine capability and methodology to conduct suppressive-type experiments and to compare the relative suppressive effects of the .50 cal and 7.62mm machineguns.

(2) <u>Objective:</u>

(a) To determine CDEC's current capabilities to induce suppressive effects during field experimentation.

(b) To identify current shortcomings in instrumentation, equipment, and methodology.

(c) To identify feasible approaches for correcting existing shortcomings.

(d) To obtain subjective opinions of the suppressive effects of selected small arms.

(e) To examine the suppressive effects of the .50 cal. machinegun simulated experimentally.

(f) To examine the suppressive effects of the 7.62mm machinegun simulated experimentally.

(g) To evaluate the relative suppressive effects of the 7.62mm machinegun simulated experimentally.

(3) Description:

(a) DUCS was a simulated live-fire experiment designed to evaluate the relative non-lethal suppressive effects of machinegun fire on an ATM gunner. A total of 48 record and 12 baseline trials were conducted.

(b) In each trial, two players, in the roles of ATM gunners, were evaluated on their ability to observe and simulate firing at attacking threat vehicles while being engaged by simulated fire.

(c) The threat consisted of two armored reconnaissance vehicles which advanced on the players' position utilizing the bounding overwatch technique. The sequence in which the threat vehicles moved and fired was developed based on the bounding overwatch technique and maximum use of the terrain for cover and concealment.

(d) Players were carefully selected to insure proper motivation, intelligence, experience and aural and visual acuity.

(4) Major Findings: The major findings in this experiment were provided in terms of answers to questions designed to satisfy experimental objectives as follows:

(a) To what degree do the effects of .50 cal. machinegun fire degrade the performance of an enemy antitank gunner? When subjected to simulated .50 cal. machinegun fire, the mean tracking (productive) time of player personnel was degraded approximately 57 percent.

(b) To what degree do the effects of 7.62mm machinegun fire degrade the performance of an enemy antitank gunner?

(1) When subjected to simulated 7.62mm machinegun fire, the mean tracking time of player personnel was degraded approximately 61 percent.

(2) When subjected to the fire of a 7.62mm machinegun firing blanks, the mean tracking time of player personnel was degraded approximately 44 percent.

(c) Which machinegun is the more suppressive weapon under controlled conditions? Using the same volume and technique of fire, it was not possible to detect a statistically significant difference between the suppressive effects of the two weapons examined.

(5) Report Availability: This was an internal CDEC methodology study. The final report is available for examination at Fort Ord.

b. Dispersion Against Concealed Targets (DACTS), July 1975

(1) Purpose: DACTS was conducted to provide data to the US Army Infantry School (USAIS) for analysis to determine the impact of various dispersion levels on the effectiveness of the future rifle system.

(2) Objectives:

(a) To provide data to evaluate the impact of variations of the man/rifle system's effective three-round burst dispersion on the effectiveness of the individual rifleman against various types of threats.

(b) To provide data on the phenomenon of suppression inducted by the effect of small arms fire.

(3) Description: DACTS was designed to provide data to evaluate semi-automatic fire and six burst dispersions obtained with modified M16 rifles (4.32mm) and standard M16A1 rifles. The experiment was conducted on three live-fire ranges. Types of targets engaged were concealed stationary, visible stationary and visible moving. Additionally, the experiment provided data on the suppressive

effects of the weapons employed and, through side tests, provided data on the distribution of personnel in an attacking squad (TERTEST), training implications related to engaging moving targets (Moving Target Range Side Test), and the ability of personnel to discern the proximity of rifle fire (Round Locating Side Test).

(4) Major Findings:

(a) Data and information collected in DACTS were keyed to the following questions:

1 What level of dispersion maximizes the effectiveness of the individual rifleman engaging visible targets?

2 What level of dispersion maximizes the effectiveness of the individual rifleman engaging concealed targets?

3 What level of dispersion maximizes the effectiveness of the fire team engaging visible targets?

4 What level of dispersion maximizes the effectiveness of the fire team engaging concealed targets?

(b) A preliminary data analysis indicated trends in the effects of burst dispersion on the performance of both the individual rifleman and the infantry fire team. However, a full data analysis was conducted by USAIS which provided conclusions and inferences on the specific effects of the variations in burst dispersions.

(5) Report Availability: A copy of the report may be obtained from DDC. (AD:B005701)

c. Suppression Experimentation Data Analysis (DAR) Report, April 1976.

(1) Purpose: The DAR provides the results of a data analysis on the suppressive effects of direct and indirect fire on soldiers under simulated combat conditions.

(2) Objectives:

(a) To determine the proximity of fire, in meters, required to suppress an antitank guided missile (ATGM) gunner with probability of 0.5 and probability of $\geq$ 0.9.

(b) To determine the volume of fire required to obtain 50 percent and 90 percent suppression of ATGM gunners.

(3) Description:

(a) The analytical results in this report addressed several types of suppression:

1 Physical Suppression. Degradation of performance of an individual or unit due to physical incapacitation such as death, injury, obscuration, or other physical constraints.

2 Unreasoned Suppression. Degradation of performance of an individual or unit due to immediately uncontrollable psychological or physiological factors such as panic, fear, fatigue, etc.

3 Reasoned Suppression. Temporary degradation in the quality of performance of a soldier or unit due to avoidance of a perceived threat from enemy weapon systems.

(b) Data used in the analysis contained in this report came from several suppression experiments conducted by CDEC. The experiments included are the Small Arms Suppression Experiment, Phase II (SASE II); Suppression Experiment, Phase I (SUPEX I);Suppression Experiment, Phase II (SUPEX II); and Artillery CDEC Experiment, Suppression (ACES).

(4) Major Findings: The data analysis revealed that:

(a) The probability of suppression is influenced by the proximity of fire in an ordered and predictable manner.

(b) The proximity of fire or radial miss distance in meters can be modeled by an experimental equation.

(5) Report Availability: A copy of this report may be obtained from DDC (AD: B10579L).

d. Suppression, July 1976

(1) Purpose: This bulletin is designed to provide commanders and troops in the field with an understanding and appreciation for the importance of suppression.

(2) Objectives:

(a) To provide information on the techniques of employing weapons in suppression roles and the relative suppressive ca-

pabilities of various weapons and countermeasures available to reduce the suppressive effects of enemy fire.

(b) To discuss training implications.

(3) Description:

(a) The information contained in this bulletin is based upon the results of a number of live fire field experiments conducted by the US Army Combat Developments Experimentation Command in 1975 and 1976.

(b) The bulletin presents various combat situations and then suggests different options the commander may exercise to provide suppressive fires and reduce enemy effectiveness.

(4) Major Findings: The findings in this bulletin are presented in terms of the results obtained after exercising various options in a given combat situation.

(5) Report Availability: A copy of this report may be obtained from the USACDEC Library.

e. Small Arms Suppression Evaluation Phase II (SASE II), August 1976

(1) Purpose: The SASE II experiment was conducted to provide data on the suppressive effects of the M16A1 (5.56mm) rifle, the M60 (7.62mm) machinegun and the M2(.50 cal) machinegun.

(2) Objectives:

(a) To obtain and quantify the level, duration and threshold of the suppressive effects that selected direct fire weapons have on defending infantry.

(b) To identify and quantify the effects that selected variables have on the suppressive effects of selected direct fire weapons employed against defending infantry.

(3) Description: For this experiment, suppression is defined as: The temporary degradation in the quality of performance of an individual due to avoidance of a perceived threat. Empirical data were collected on the ability of soldiers to perform combat-related tasks while receiving fire. The conditions under which the fire was delivered

were controlled and varied by the experiment design. Therefore, data collected on variations of performance are measures of suppression. The experiment was conducted in eight parts with each part designed to contribute selected data in support of the overall purpose and objectives of the experiment. During each part, the suppressive effects of fire delivered against infantrymen concealed in defensive positions were evaluated. Two supplemental data analysis reports were also prepared for the SASE II Experiment:

(a) SASE II Analysis Report (Vol II) July 1976

(b) BDMSC SASE II Analysis Report August 1976

(4) <u>Major Findings</u>:

(a) The M2 machinegun was shown to be significantly more suppressive than the M60 machinegun, which in turn, was significantly more suppressive than the M16A1 rifle.

(b) The number of rounds (e.g., 3 vs. 6) of ball ammunition per burst of automatic fire has little or no effect on the suppressiveness of the fire. However, the time interval (e.g., 4 sec vs. 12 sec) between bursts has a significant effect.

(c) Suppresive fire delivered in small bursts with short time intervals between bursts appears to be most efficient for delivering suppressive fires.

(d) The degree that a soldier is suppressed by incoming fire can be approximated by a mathematical model which includes the natural logarithm of his distance to the incoming fire.

(e) Classes (or techniques) of fire affect the suppressiveness of the fire. Classes of fire which result in a random distribution of fire throughout the target area are more suppressive than classes which result in fire being distributed in a systematic pattern.

(f) Soldiers who have received indoctrination stressing the lethality and dangerousness of weapon systems are more suppressed (40%) by the systems than soldiers who have not been indoctrinated.

(g) Soldiers operating independently were found to be more suppressed (43% to 115%) under similar conditions than collocated soldiers operating in groups.

(h) Soldiers defending from frontal parapet foxholes were significantly less suppressed (62%) than soldiers defending from standard foxholes.

(i) Suppression is affected both by the overall situation under which fires are delivered and by the individual bursts of fire.

(5) Report Availability: (AD B013211)

The availability of these reports are as follows:

(a) SASE II Experimental Report - DDC (AD B0132102)

(b) SASE II Analysis Report (Vol II) - USACDEC Library

(c) BDMSC SASE II Analysis Report - USACDEC Library

f. Suppression Experiment (SUPEX), February 1977

(1) Purpose: The SUPEX experiment was conducted to provide comparative evaluations of the suppressive effects of selected weapon systems ranging from the M16A2 rifle to the 8-inch Howitzer.

(2) Objectives:

(a) To determine the proximity of fire required to suppress a threat antitank missile gunner with a single round or burst with probabilities of .5 and .9.

(b) To determine the volume of fire required by each weapon system to sustain 50% and 90% suppression of a threat element employing antitank guided missiles along 100m and 500m fronts.

(3) Description: SUPEX was conducted in two phases. During Phase I, the M16A1 rifle, M3 submachinegun, .50 cal. machinegun (MG), 20mm cannon, and 40mm High Velocity Grenade Launcher (HVGL) were evaluated. The latter three weapons were tested with the players located in individual protective bunkers and by firing at targets immediately to their front. A silhouette target, which represented the player and over which he had control, was placed directly in front of the bunker and electrically wired in such a manner that when the player raised his periscope, the silhouette went up and when the player lowered his periscope,

the silhouette went down. The players' mission was to acquire target tanks and simulate firing an antitank missile at these targets located at ranges of approximately 1400 meters. The players were instructed to respond to incoming rounds by lowering or raising their periscopes as they believed they would if they were the silhouette immediately to the front of their foxhole. The raising and lowering of the periscopes was automatically recorded and an analysis performed on the percent of the players that suppressed as a function of the distance that a round impacted from the player's silhouette.

(4) Major Findings: The findings were presented in the form of probability curves and data tables. These findings revealed the proximity within which single rounds and five-round bursts of various weapon systems must impact to achieve a .5 and .9 probability of suppression.

(5) Report Availability: A copy of this report may be obtained from DDC (B017116).

g. Suppression Experimentation Supplemental Data Analysis (SESDA), May 1977

(1) Purpose: The SESDA report was prepared to provide suppression data results from selected trials of the Small Arms Suppression Experiment (SASE II) conducted by CDEC.

(2) Objectives:

(a) To determine the proximity of fire, in meters, required to suppress an individual infantryman with probability of 0.5 and probability of 0.9 under each of the experimentation conditions.

(b) To determine the effects on the suppression of infantrymen due to:

1 Rate of fire

2 Selected patterns of weapon fire

3 Type of ammunition at night.

(3) Description: Empirical data were collected on the ability of soldiers to perform combat related tasks while receiving fire. The conditions under which the fire was delivered were controlled and varied by the experiment design. Data collected on performance variations provide measures of the effects of the experiment treatments on suppression. The experiment was conducted in parts with each part designed to contribute selected data in support of the overall purpose and objectives of the experiment.

(4) Major Findings:

(a) In general, a six-round burst of fire from the M2 machinegun has a higher probability of suppressing players than a six-round burst from the M60 machinegun under all conditions examined.

(b) The probability that a six-round burst would suppress players generally decreased for both the M2 and M60 machinegun as the radial miss distance of the impacting fire increased.

(c) Generally, bursts of fire using the traversing patterns had a higher probability of suppressing players at a given miss distance than bursts of fire using the pseudorandom techniques of fire.

(d) In general, bursts of fire directed overhead by the M60 machinegun at a player's position had relatively the same probability of suppressing the player as did bursts of fire directed into the berm forward of the player.

(5) Report Availability: A copy of this report may be obtained from the CDEC Library.

h. Suppression Experiment IIIA (SUPEX IIIA), June 1978

(1) Purpose: The SUPEX IIIA Experiment was conducted to determine the methodology which would provide the most credible field environment to gather suppression data while insuring adequate player safety.

(2) Objectives:

(a) To compare the probabilities of suppressing an ATGM gunner (with simulated rounds) when using an "open" versus a "closed" foxhole.

(b) To compare the probabilities of suppressing an Antitank Guided Missile (ATGM) gunner in a covered foxhole when high explosive projectiles were detonated and when simulated rounds were detonated.

(3) Description: SUPEX IIIA was a methodology experiment designed to compare individual responses to suppression effects induced by selected live, indirect fire munitions (81mm and 155mm) and their simulated rounds, and to evaluate two foxhole types. Also, to select the best techniques and procedures to be used in future suppression experiments while insuring the absolute safety of the players.

(4) Major Findings:

(a) There is no statistically significant difference between live round, closed foxhole conditions, and the simulated round, closed foxhole condition with a 81mm round.

(b) There is no statistically significant difference between the open and the closed foxhole using a simulated 81mm round.

(c) There is no significant difference between live rounds closed foxhole and simulated rounds closed hole.

(d) The simulated/closed condition is significantly less suppressive than the simulated/open conditfon for the 155mm round.

(5) Report Availability: A copy of this report may be obtained from the CDEC Library.

i. Suppression Experiment IIIB (SUPEX IIIB), November 1978

(1) Purpose: The SUPEX IIIB was conducted to generate data and measure the reasoned suppression produced by statically detonated surface bursts of 60mm mortar, 81mm mortar, 105mm Howitzer, and 155mm Howitzer rounds.

(2) Objectives:

(a) To determine the probability of suppressing an Antitank Guided Missile (ATGM) gunner with single rounds as a function of detonation distance and aspect angle from the gunner.

(b) To gain insights into the probability of suppressing an ATGM gunner with volley fires from 105mm and 155mm Howitzers (surface burst).

(c) To gain insights into the effect of obscuration on the probability of suppressing an ATGM gunner with the various type detonations. This objective was added to the test after the project analysis was published.

(3) Description: The experiment was designed to examine the players' responses induced by the exploding simulated munitions. It was a one-sided live fire experiment employing statically detonated 60mm, 80mm, 105mm, and 155mm simulated rounds. These simulated rounds were detonated as ground bursts. Player personnel were placed in open foxholes in close proximity to the detonating munitions. Using an instrumented prototype sight, players were required to detect and simulate engagement of a moving target vehicle while statically detonated munitions were exploded on the ground at specified distances and aspect angles from his position. Limited volley fire trials were executed to gain insights into the effects of volley fire (105mm and 155mm simulated rounds) compared to single round fire on the reaction of an individual soldier. It was assumed that 6 tubes of artillery would fire a volley at a given point with no adjustments being made on the impacting rounds.

(4) Major Findings:

(a) For any given range and round size, the most suppressive detonations observed were directly in front of the player (0 degrees). The observed least suppressive detonation varied for each round size, but always behind the player. (The least suppressive aspect angle for 60mm, 81mm, 105mm and 155mm was 180, 150, 180 and 210 degrees, respectively).

(b) The most suppressive detonations during the volley fire were located to the player's front (0 degrees) and the least suppressive detonations were generally at 90 or 180 degrees.

(c) For single round detonations, when obscuration of the target vehicle was reported, the angle between the target vehicle and the detonation measured from the player's vantage point was generally between ± 45 degrees.

(d) Human factors questionnaire results and individual interviews showed the players regarded the experiment as a very realistic training, particularly during the volley trials.

(5) Report Availability: A copy of this report may be obtained from DDC (B034851L).

3. RESULTS SUMMARY: Table I shows the weapons which are treated in each of the reports described in the preceding paragraphs. Tables II and III compare the results of these experiments. DAR is the Data Analysis Report based on several sources of suppression data.

	DUCS	DACTS	ANALYSIS	SASE II	BULLETIN	SASE II ANALYSIS	SUPEX	SESDA	SUPEX IIIA	SUPEX III
M-3			x				x			
M-16A1(5.56mm)		x	x	x	x	x	x			
M-16(4.32mm)		x								
M-60	x		x	x	x	x		x		x
M-2	x		x	x	x	x	x	x		
M139(20mm)			x		x		x			
MK19(40mm)			x		x		x			
60mm mortar			x				x			
81mm mortar			x	x	x		x		x	x
2.75" rocket			x				x			
90mm RR			x							
105 How (grd)			x		x		x			x
105 HEP-T			x		x		x			
4.2 mortar (grd)			x		x					
155 How (grd)			x		x		x		x	x
8" How (grd)			x				x			
4.2 mortar (air)			x		x					
105 How (air)			x		x					
155 How (air)			x		x					
8" How (air)			x							

TABLE I

PROXIMITY OF FIRE REQUIRED FOR GIVEN

PROBABILITY OF SUPPRESSION

WEAPON	P(S)=.50			P(S)=.90		
	DAR	SUPEX	SUPEX III	DAR	SUPEX	SUPEX III
M-3	3	1	0	0	0	0
M-16A1	3	1	0	0	0	0
M-2	24	26	0	5	8	0
M139	30	39	0	7	14	0
MK19	59	70	0	9	20	0
60mm	35	48	46	21	24	16
81mm	72	87	58	34	41	15
105 How	118	91	51	55	46	21
105 HEP-T	93	93	0	43	49	0
2.75"	84	83	0	43	44	0
155mm	144	106	104	77	72	63
8"	392	257	0	169	126	0

TABLE II

VOLUME OF FIRE NECESSARY TO CAUSE GIVEN PERCENT

OF SUPPRESSION OVER A 100 (or 500) METER FRONT

(RDS per minute)

WEAPON	FRONT	50% DAR	50% SUPEX	90% DAR	90% SUPEX
M-3	100	103	135	342	450
M-16A1	100	88	128	293	413
M-2	100	23	25	75	100
M139	100	19	25	63	75
MK19	100	16	25	45	50
60mm	500	17	15	47	50
81mm	500	8	10	24	25
105 How	500	5	10	15	25
105 HEP-T	500	6	10	19	25
2.75"	500	7	10	20	30
155mm	500	4	10	12	25
8"	500	2	5	5	10

For larger caliber indirect fire weapons, the two integrating techniques differ markedly. The repetition of the 10 and the 25 in the SUPEX is a peculiarity of the scenario used, not an indication that those weapons are equally effective.

TABLE III

D. "Suppression w/Data from Yom Kippur War" - Mr Paul Kunselman, Physicist with Tactical Operations Office, AMSAA

SLIDE #1

US ARMY MATERIEL SYSTEMS ANALYSIS ACTIVITY

SUPPRESSION ESTIMATES IN DIVLEV

P. KUNSELMAN

T. ROUSE

K. BUTLER

SLIDE #2

SUPPRESSION BY FIRE IN DIVLEV

- DIRECT FIRE SUPPRESSION OF DIRECT FIRE WEAPONS
- ARTILLERY SUPPRESSION OF MANEUVER UNITS (DIRECT FIRE WEAPONS)
- ARTILLERY SUPPRESSION OF ARTILLERY WEAPONS

SLIDE #3

DIVLEV OVERVIEW

- TWO SIDED WARGAME
- PLAYER CONTROLLED, COMPUTER ASSISTED
- RESOLUTION - COMPANY MANEUVER UNITS
  - ARTILLERY BATTERY
- SEVERAL DIVISIONS ON EACH SIDE

2 PRIMARY PRODUCT - DETAILED TIME DEPENDENT COMBAT SCENARIOS

SLIDE #4

SUPPRESSION BY FIRE

FEAR - PRUDENCE - OBSCURATION

SLIDE #5

DIRECT FIRE ⟶ DIRECT FIRE

ASSUMPTIONS

- FRACTION OF DIRECT FIRE WEAPONS IN SUPPRESSED STATE (λ)

  $$\lambda = 1 - e^{-CF(X)}$$

  $C > 0$, SUPPRESSION CONST.

  $F(X) \Longrightarrow$ SOME FUNCTION OF SUPPRESSING FORCE STRENGTH, (X)

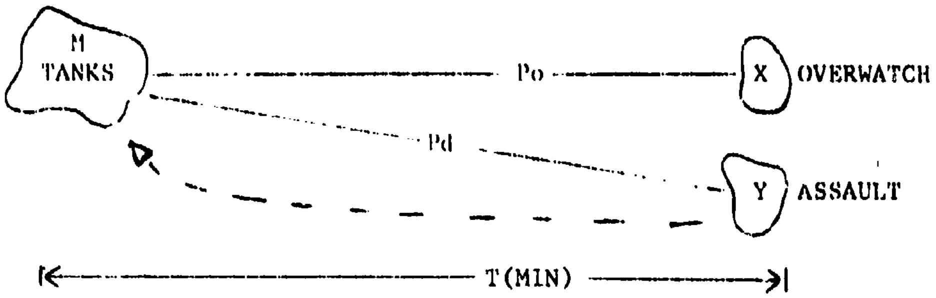
- ATTACKING FORCE: DEFENDING FORCE = 3:1
- DEFENDER NOT "HARDENED" BUT IN HASTY PREPARED DEFENSIVE SITE
- THE ATTACKING CDR WILL MAXIMIZE THE NUMBER OF ATTACKERS REACHING THE DEFENDER'S POSITION BY ALLOCATING 1/3 OF ATTACKING FORCE TO RESERVE & OVERWATCH AND 2/3 OF ATTACKING FORCE TO ASSAULT.

SLIDE #6

DESIGN SCENARIO

DEFENDER (M) ATTACKER (N)

KILL RATE



- o $Y(T) = Y(0) - Pd \cdot T \cdot MunSup$
- o $Y(T) = (N-X) - Pd \cdot T \cdot e^{-CF(X)} \cdot M$

- -

- o $\frac{dY(T)}{dX} = 0$, USING $F(X) = \frac{PoX}{M}$
- o $1 + Pd\ Po\ T \cdot C \cdot e^{-C\frac{PoX}{M}} = 0$
- o $N = 3M$, $X = 1/3N$

$$\boxed{\ln C = Po\ C - \ln PoPdT}$$

SLIDE #7

DIRECT FIRE SUPPRESSION CONSTANT

Po = .036 DEFILADE TANKS KILLED/MIN/TANK WPN

Pd = .74 MOVING EXPOSED TANKS KILLED/MIN/TANK WPN

T = 5 MIN

SUPPRESSION CONST	% DEFENDER SUPPRESSED	ASSAULT FORCE REMAINING
C	λ	Y (T)
11	33%	- .16N
55	87%	.49N (25% LOST)

SLIDE #8

DIRECT FIRE ⟶ DIRECT FIRE

APPLICATION IN DIVLEV

$$\boxed{\underbrace{\lambda(T)}_{\text{FRACTION TARGET SUPPRESSED}} = 1 - \text{EXP}\left[(-55.6)\cdot\underbrace{\left(\frac{\text{KILL RATE ON TARGET (T)}}{\text{TARGET STRENGTH (T)}}\right)}_{\text{POTENTIAL KILL FUNCTION AT TARGET}}\right]}$$

SLIDE #9

TANK LOSSES

	FORCE	STRENGTH	ACTUAL LOSSES	DIVLEV	DURATION
CASE 1	BLUE	20	2	4.9 - 17.4	20-57 (60)
	RED	30	7	1.3 - 6.9	
CASE 2	BLUE	8	3	7.5	6 (45)
	RED	20	11	9.8	
CASE 3	BLUE	14	0	0	10 (53)
	RED	20	6	20	

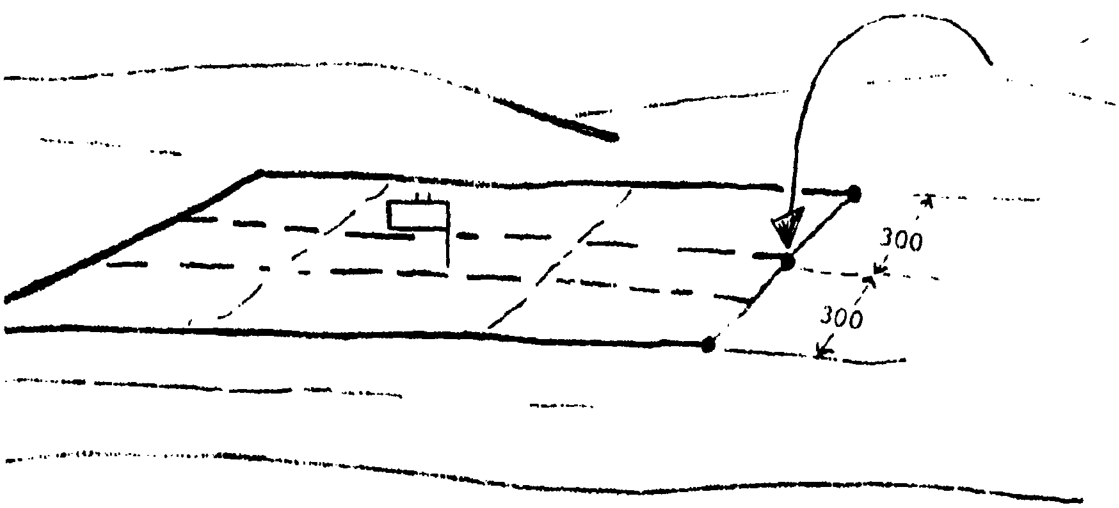
SLIDE #10

TANK LOSSES

GAME	FORCE	STARTING STRENGTH	ACTUAL LOSSES	DIVLEV LOSSES	ACTUAL DURATION	DIVLEV DURATION
CASE 1	BLUE	20	2	1.4	60 MIN	60 MIN
	RED	30	7	7.3		
CASE 2	BLUE	8	3	2.4	45 MIN	45 MIN
	RED	20	11	10.8		
CASE 3	BLUE	14	0	0	53 MIN	53 MIN
	RED	20	6	6.6		

SLIDE #11

MANEUVER UNITS



NAB = #ARTY BTRYS TARGETED ON UNIT
TFCP = #300 METER SEGMENTS IN FRONT OF UNIT

$$Sm(t) = 1 - e^{-.693\,(NAB(t)/TFCP(t))}$$

$$= .5 \qquad (NAB = TFCP)$$

$$Ss(t) = 1 - e^{-1.386\,(NAB(t)/TFCP(t))}$$

$$= .75 \qquad (NAB = TFCP)$$

PORTION OF UNIT SUPPRESSED IS NOT ALLOWED TO MOVE, FIRE, OR BE FIRED ON BY DIRECT FIRE WEAPONS

SLIDE #12

ARTILLERY SUPPRESSION OF ARTILLERY UNITS

1 BTRY vs 1 BTRY

- FIRST ATTACK: TOTAL SUPPRESSION DURING PERIOD OF ATTACK AND SUBSEQUENT 15 MIN (SMALL DISPLACEMENT)
- SUBSEQUENT ATTACKS: (WITHIN 5 HRS): TOTAL SUPPRESSION DURING PERIOD OF ATTACK AND SUBSEQUENT 30 MIN (LARGER DISPLACEMENT)

ROUNDS MUST FUNCTION WITHIN 150 METERS OF BTRY CENTER

ARMORED ARTY, MISSIONS BEING PERFORMED ARE COMPLETED BEFORE SUPPRESSION TAKES EFFECT.

SLIDE #13

SUPPRESSION BY FIRE

FEAR — $\boxed{\text{PRUDENCE}}$ — OBSCURATION

OTHER SUPPRESSION MEANS

- SMOKE DELIVERED BY ARTILLERY
- DEAD TIME - DIRECT FIRE KILL RATES
- EW
- FIGHTING EFFICIENCY

E. "Suppression of Enemy Air Defense (SEAD)" - LTC Kenneth Redding, United States Air Force Representative at Fort Sill

General Dinges, Ladies and Gentlemen, this afternoon I offer a departure from this morning's speakers. That is, I will present no models, no specific dates, nor will I get deep into roles and missions. Instead, I will give a report on USAF efforts in the area of Suppression of Enemy Air Defense (SEAD) and will conclude with an idea for your consideration as we go into our study groups.

In February 1979, General Creech, Commander of Tactical Air Command (TAC), directed the Commander of Green Flag to begin work on a SEAD concept. Let me explain that Flag organizations in TAC are tasked with conducting exercises which evaluate units, equipment and concepts. For example, the Red Flag involves combat exercises, Blue Flag deals with command and control, Gray Flag tests maintenance, and now, Green Flag will be responsible for SEAD. In April 1979, Green Flag queried various USAF units attached to Army installations for inputs into the directed study. Today, this week, there is a Green Flag conference at Eglin AFB, Florida which is attempting to define terms and quantify data in much the same matter as we are doing in this symposium. After Green Flag develops a command approved concept, the plan is to test it in a Red Flag/Blue Flag environment. Now I would like to move from current efforts to future requirements.

Name one factor that colors the entire USAF Offensive Air Support (OAS) picture and you would have to pick the Soviet mobile SAM concept with its redundant target coverage. It has forced us to change our tactics from those used in Southeast Asia to those presently used, i.e., low level, in order to increase aircraft survivability and, in the long term, OAS effectiveness.

Closely linked to survivability is effective suppression which leads me to my main point: TACAIR must have suppression, specifically SEAD (SAM and AAA) in order to be effective in the hostile environment previously mentioned. Now there are, generally speaking, two ways we can obtain this suppression:

1. We (USAF) can provide SEAD ourselves by forming a Strike/Support aircraft package. This fighter group would be composed of a given number of strike aircraft led by a pathfinder or escort fighter aircraft. Accompanying the strike element would be support aircraft with specialized roles, i.e., chaff dispensing, Mig Cap, and electronic counter measures. These aircrafts would be preceded by reconnaissance aircraft which would provide the main force with target information. Most of us can remember the large aircraft raids into North Viet Nam. For illustration purposes let's say the raid force was 100 aircraft. That looked impressive, 100 aircraft going up North at one time, but on closer examination you would find maybe 50 of the aircraft carrying iron bombs; the rest were support aircraft. Now with the force just described, you could expect an acceptable degree of suppression but look at the cost. Since we deal with a finite number of aircraft we must get the support aircraft from somewhere. So, we rob Peter to pay Paul. 2. Better that we try to maximize the number of strike aircraft available for OAS. We can do this by utilizing the other means of suppression - joint SEAD. By using Army assets, such as artillery, Vulcans, armed helicopter, mortars or the long range Nike, together with USAF capabilities you have the best of the two suppression systems. I conclude by restating the USAF believes in SEAD, we need it to survive tomorrow's battle.

F. "Human Behavior in Combat" - COL (Ret) Trevor N. Dupuy, Noted Author, President, T. N. Dupuy Associates

HUMAN BEHAVIOR IN COMBAT:

WITH A FOCUS ON SUPPRESSION

By

Colonel T. N. Dupuy

I have been asked to provide some insights gleaned from military history about human behavior in combat, as it may be relevant to our conference topic of "Suppression".

Before I address myself to the specifics of this, I want to make sure that you all recognize that there are two kinds of military history:

There is military history cited (often erroneously) to support preconceived ideas, and there is analytical military history based upon objective and comprehensive (as opposed to selective) assessment of all available and relevant facts. Obviously, no one would plead guilty to serving up distorted military history. To use a non-military historical analogy, all bootleggers of the 1920's and 30's assured their customers that they were selling stuff right off the boat; none would admit that he was really peddling home-grown and colored, raw corn whiskey.

So, you are warned. Be skeptical about all military historical facts cited to you -- including mine. But just because you are skeptical, don't discount it; merely make sure that you are not being sold a bill of goods.

Let me give you some examples of distorted military history -- relevant to my topic of human behavior in combat -- from recent articles in military journals.

It is popular these days to try to encourage the troops by assuring them that it is perfectly reasonable to expect that we can and should be able to fight outnumbered and win. My examples are of this genre of encouragement via "military history" in military journals.

In one recent article the author gave several instances of "fighting outnumbered and winning." Three particularly interested me:

1. The Spartan defense of Themopylae.
2. Wellington's victory over Napoleon at Waterloo.
3. The American recovery and victory over the German onslaught at the Battle of the Bulge, in 1944.

There is just one problem about all of these examples. The victorious side outnumbered the losing side by margins of two-to-one or greater. In all three instances the losing side had higher combat effectiveness than the winners, but they were overwhelmed by superior numbers.

In another article, the author tried to demonstrate that relative numerical strength is unimportant to combat outcomes by reminding the reader that in most of Creasy's Fifteen Decisive Battles of the World the numerically inferior force won. If this statement were true it would be a very powerful argument. It's too bad that in eleven of those fifteen battles the numerically superior force won.

In other words, these historical examples really demonstrated just the opposite of what the authors were trying to prove. This sort of thing can give military history a bad name!!!

On this matter of relevance of numbers, let me quote from Clausewitz - "If we... strip the engagement of all the variables arising from its purpose and circumstances, and disregard (or strip out) the fighting value of the troops involved (which is a given quantity), we are left with the bare concept of the engagement...in which the only distinguishing factor is the number of troops on either side."

"These numbers, therefore, will determine victory...superiority of numbers in a given engagement is only one of the factors that determines victory (but) is the most important factor in the outcome of an engagement, so long as it is great enough to counterbalance all other contributing circumstances."

"This...would hold true for Greeks and Persians, for Englishmen and Mahrattas, for Frenchmen and Germans."*

*Karl von Clausewitcz, On War
Book 3, Chapter 8

Over the past several years I have been devoting a substantial proportion of my time to consideration of the combat "variables" mentioned by Clausewitz considering not only those that are physical, tangible, and measurable, but those relating to what he called "the fighting value of the troops" -- in other words, the effects of behavioral considerations on military performance and on battle outcomes. By physical variables I mean such things as the measurable effects of weapons, of weather, of terrain, of armored protection, of vehicle capabilities, and the like. By behavioral considerations I mean such things as the effects of surprise, leadership, training, logistics capabilities, morale, and disruption. My colleagues and I have estimated that there are 77 types of elements or variables which interact to produce combat outcomes and of these 18 are behavioral. If we ever find a way to calculate such things -- and some day I believe we will -- we will probably find the 18 behavioral factors are potentially at least twice as important as the 59 physical elements or effects.

Although I have not yet found a way to measure consistently the effects of the variable factors that I call the "qualitative intangibles" -- those that related to what Clausewitz called the "fighting value (or quality) of the troops", and to their leadership and control systems -- I am satisfied that it is possible to determine an overall, consolidated qualitative intangibles in any historical battle, and that this consolidated value can be termed Relative Combat Effectiveness, or CEV. For instance, analyses of more than 100 World War II engagements have demonstrated some very clear patterns of relative combat effectiveness of the major participants. On the average, the Germans had a relative CEV of 1.2

with respect to the Western Allies -- the British and Americans. In other words, 100 Germans in ground military formations were roughly equivalent in combat capability to 120 Americans or Britishers. The average Geman CEV with respect to the Soviets was a whopping 2.5; or 100 Germans were the combat equivalent of about 250 Russian soldiers in combat units. Similarly, in analyses of about 50 engagements of the 1967 and 1973 Middle East Wars, it is evident that the Israelis had a relative Combat Effectiveness Value of about 2.0 with respect to their Arab opponents; or, 100 Israelis in ground combat units were the equivalent of about 200 Arabs.

Incidentally, it is this qualitative factor of Relative Combat Effectiveness - what Clausewitz called the fighting value of the troops - that provides the explanation for most cases in which a numerically inferior force -- without the benefit of defensive posture -- defeated a larger force.

This might be a good time for me to mention one of the reasons why I believe military history is relevant to modern warfare, despite its more sophisticated technology and greater lethality of weapons.

For all of the changes that have taken place in weapons over the course of recorded history, one important element has remained constant: Man, and human behavior in the lethal environment of combat. Because of that constant element of war, some aspects of combat have not changed, and are as true today as they were in the time of Alexander the Great.

Thus, if we wish to forecast the effects of new technology and untested weapons on future combat, we must relate the known effects of this technology and these new weapons to those things that have not changed -- the timeless verities of combat, I call them.

I have listed some Thirteen Timeless Verities of Combat which I believe provide a base for forecasting. But tonight I only want to mention six, which I believe are of particular importance to our purposes. These are:

1. The side which obtains the initiative (either because of greater strength, or greater skill) can apply greater combat power at a given time and place than can its opponent.

2. Other things being equal, victory goes to the side with the combat power preponderance; i.e., if opponents are comparable in skill and weaponry, and allowance is made for defensive posture, superior numbers always win.

3. The combat power of a force which achieves surprise is substantially enhanced, and can be doubled or tripled.

4. Fire kills; fire disrupts; fire suppresses; fire causes dispersion.

5. In combat all military activites are slower, less productive, and less efficient than anticipated in peacetime tests, plans, and training exercises.

6. Combat is too complex to be described in a single, simple aphorism.

Let me amplify just a bit about some of the behavioral factors that contribute to these timeless verities. Of course, not all of the behavioral factors are

always operative. Take, for instance, surprise. My colleagues and I have learned from experience in analyzing a number of engagements, those in which surprise influenced the outcome, it is possible to discern clear-cut effects on both the mobility and vulnerability of the opposite forces. So, like terrain, posture, weather effects, we can assign specific (and we hope relatively precise) multiplier values to the effects of surprise on mobility and vulnerability. Thus, I do not consider surprise to be an intangible, like leadership, or training, or experience.

Therefore, I call these behavioral variables -- which may or may not be operative in an engagement -- "emphemeral, reactive factors." These are emphemeral, and they are reactive, and of course (like the qualitative intangibles) they are essentially behavioral.

For the moment I am assuming that disruption caused by a combat process other than surprise will include the effects of suppression. Further research may reveal that suppression is a very distinct form of disruption, that can be measured or estimated quite independently of disruption caused by any other phenomenon -- such as a communications breakdown, which certainly would be degrading and probably disruptive.

This leads me to mention again something you may have already heard me say a couple of times: There is a need for rigor in the use of such overlapping -- but not synonomous -- terms as disruption, degradation and suppression.

Someone in Working Group III said we should not let ourselves get bogged down in the details of definitions. My response is: Let's be sure not only that we know what we are talking about, but that we can communicate with each other.

In the light of the discussions we have had, it might be useful if I gave you my definition of suppression. It is similar to the one Colonel Pokorny put on the screen, but there is a difference that might be significant: "Suppression is the degradation of hostile operational capabilities through the employment of military action which has psychological or physical effects impairing the combat performance of enemy forces and individuals who have not themselves been rendered casualties."

Note I focus not on the means of suppression, but on the effects. Once we fully understand the effect, the means will take care of themselves.

It is not appropriate in this presentation for me to make a pitch for any particular methodology for trying to come to grips with this phenomenon of suppression. I have some firm ideas about this, which I have put in the form of proposals and a "think piece" which was recently published in a professional journal.

But - at the risk of boring those who are in Working Group II - I do think it is appropriate for me to indicate how I think the experience of military history can help us in our efforts to come to grips with the elusive topic. First, let me remind you that, by analysis of historical battle outcomes, it has been possible to arrive at consistent values for the effects of surprise and of superior combat effectiveness on the battlefield. Without military

history it would have been utterly impossible to arrive at such quantitative values for these essentially qualitative, behavioral phenomena. No one was able to offer more than wild guesses about these combat processes effects until my colleagues and I showed that they could be distilled from the materials available in the laboratory of the soldier: military history.

I can see no possibility of arriving at values for suppression by any process that is not equally dependent upon the resources available in this laboratory of the soldier. No test, no experiment, can possibly reproduce the conditions which are the essence of suppression: human fear in a lethal environment.

Let me demonstrate why I believe something can be done about this matter -- and at the same time demonstrate why it is important that it be done. I'll deal with this latter point first.

It is important that we be able to deal with the phenomenon of suppression because it undoubtedly affects battle outcomes, and if we cannot find some way of representing it in our models, then we cannot expect our models to give us results in which we can have confidence. I hope that this is self-evident. I hope that no one here thinks that if we cannot measure it, or reliably represent it, that it can, therefore, be ignored, or only be considered every four years, as suggested by Roger Willis.

Yet in effect, despite what Roger said we're largely ignoring the effects of suppression, particularly in our more aggregated models.

Take CEM, for instance. And I mention CEM only because it provides me with an opportunity to make a very specific and very important point, not because it is any less reliable than other models in this or any other respect.

In CEM the effect of artillery fire is represented in ammunition tonnages. In some uses of CEM, this artillery tonnage is converted to "155MM equivalents."

Now, then, let me refer you to a British Operations Research report of a post-World War II analysis of several engagements in which suppressive effects of artillery fire were assessed. By careful study of the data: opposing strengths, casualties, amount of artillery ammunition expended, rates of artillery fire, nature of defensive protection, and the like, the British OR analysis were able to determine a number of critical facts about the suppressive effect of artillery fire, such as the duration and intensity of fire required to achieve a given suppressive effect.

Now, one of the things that emerged clearly from this analysis was the following, and I quote:

"There is the question of numbers of shells as opposed to sheer weight -- the age-old argument in another form of field versus medium artillery. There are a lot of jobs where the heavier shells are essential, either because of their greater range or greater penetration and explosive powers. But where lighter stuff can reach, and is capable of hurting the enemy, the evidence of these two reports seems to be that the thing that counts most of all is the number of bangs. Clearly one 100 pounder shell is better than one 25 pounder one. It is

on the other hand very questionable whether it is four times better."*

*Number 2 Operational Research Section Report to the Army Council, "Operational research in NW Europe," London, c. 1946, p 185.

(This report, incidentally, is available in the Morris Swett Library here at Fort Sill.)

Now, then, let's look at this British finding about suppression from historical combat analysis, to see how it is relevant to the CEM method of measuring artillery effect. If CEM were to show 100 tons of artillery ammunition fired in a target area in a given period, that could be some 400 rounds of 8" ammunition, it could be about 2,000 rounds of 155MM ammunition, or it could be approximately 4,000 rounds of 105MM ammunition. Is there anyone in this room who even without the British report -- believes that the same suppressive effect can be achieved with 400 8" rounds in a given period of time as by 4,000 105MM rounds in the same amount of time?

Dinner talks should not be long. They should be provocative. I hope I have provoked some of you into exploring how combat historical data can help us understand, measure, and represent the phenomenon of suppression.

SECTION IV: WORK GROUP SUBJECTS AND PARTICIPANTS

Work Group I - Suppression Variables (Effects)

Members: Mr. Goldberg - Group Leader
Dr. Banderet, USA Inst Environ Medicine
Mr. Downs, BRL
Mr. Giordano, HEL
Mr. Kunselman, AMSAA
Mr. Bauman, Fort Knox
Dr. Plotkin, Mitre Corp
Colonel Buel, TRADOC/USAFAS Representative
Dr. Hegge, Walter Reed
Dr. Chambers, ARI

Work Group II - Suppression Variables (Causes)

Members: Mr. Hardison - Group Leader
Colonel Crawford, TSM Smoke
Lieutenant Colonel Stokes, USA Inst Environ Medicine
Dr. Burleson, TRASANA
Mr. Garrett, AMSAA
Mr. Landry, SPC
Mr. Lynch, Boeing Aerospace
Colonel Lamons, TRADOC/USAFAS Representative
Mr. C.R. Holt, Mitre Corp

Work Group III - Data Base Requirements

Members: Dr. Bryson, CDEC - Group Leader
Colonel (Ret) Dupuy, TND
Captain Lawson, DNA
Mr. Cline, SPC
Mrs. Shirley, Infantry School
Mr. Brown, Boeing Aerospace
Colonel Pokorny, TRADOC/USAFAS Representative
Dr. Leake, Armor & Eng Board
Mr. Loveless, USAFAS

Work Group IV - Suppression Modeling

Members: Dr. Payne - Group Leader
Colonel Reed, CAC
Captain (P) Wallace, Fort Knox
Dr. Dubin, AMSAA
Mr. Gividen, ARI
Mr. Weiss, Litton
Dr. Blum, Vector Research
Colonel Slater, TRADOC/USAFAS Representative
Mr Porreca, R&D Associates
Mr. Thorp, TRASANA
Mr. Millspaugh, USAFAS

Work Group V - Suppression/Countersuppression Combat and Training Developments.

Members: Mr. Murphy, SAI - Group Leader
Major Graham, Infantry School
Major Money, Fort Rucker
Captain Gunderson, AMSAA
Lieutenant Colonel Bacon, TSM Smoke
Colonel Quinlan, TRADOC/USAFAS Representative
Major Johnston, Fort Bliss
Major Kalla, AMSAA

SECTION V: SECOND AND THIRD SESSION-WORK GROUPS' RESULTS

A. Group I: Suppression Variables (Effects)

B. Group II: Suppression Variables (Causes)

C. Group III: Data Base Requirements

D. Group IV: Suppression Modeling

E. Group V: Suppression/Countersuppression Combat and Training Developments

A. Group I: Suppression Variables (Effects)

Members: Mr. Goldberg - Group Leader
Dr. Banderet, USA Inst Environ Medicine
Mr. Downs, BRL
Mr. Giordano, HEL
Mr. Kunselman, AMSAA
Mr. Bauman, Fort Knox
Dr. Plotkin, Mitre Corp
Colonel Buel, TRADOC/USAFAS Representative
Dr. Hegge, Walter Reed
Dr. Chambers, ARI

In order to focus its effort Group I had the following goals and questions/issues:

1. Goals:

   a. Identify significant variables

   b. Prioritize their importance

2. Questions/Issues:

   a. What unit/individual functions are suppressed?

   b. What is the extent (quantity, time length) of suppression?

   c. What are the aggregate effects of suppression on weapon system/unit?

   d. How does unit/individual "battle history" affect suppression vulnerabilities?

The Group I Report

Suppression is something like Mark Twain's view of the Washington weather "Everyone talks about it, but no one does anything about it". Air conditioning may have helped to alleviate the Washington problem. Although there are some piecemeal efforts on suppression of dismounted troops, the Army has yet to develop an overall view and hence an overall program on what suppression is, what causes it, and what its effects are.

. First a brief account of what has been done -

- In connection with Army Small Arms Requirements effort and the ASARS Battle model developed to support it, data was gathered from Vietnam veterans about the results of suppression. These were consolidated into seven categories of increasing severity, based on the results of suppression on an individual's ability to move, shoot and observe. A CDEC experiment was then conducted in which small arms of various calibers were fired overhead and to the side of individual soldiers - all combat veterans. These individuals related the round and distance to one of the seven categories. The Infantry School at the same time through a large scale questionnaire and a Delphi evaluation technique, quantified the amount of degradation of individual performance. It was now possible to relate quantitatively the performance of a particular round of small arms ammunition to its suppressive effect. These quantities have been incorporated into the ASARS Battle model and are presently being used in the SAW COEA.

Litton Corporation, under contract developed subjectively another model to quantify the suppression effects of exploding munitions, principally artillery rounds, against dismounted troops. While the model is still being used, it has not been well accepted. In order to develop better data, CDEC has conducted two experiments, SUPEX II AND SUPEX III to quantify this suppression effect. Much progress has been made, but adequate realism does not yet appear to have been achieved, and the results of these two experiments have not been specifically approved by HQ TRADOC. The techniques which they have developed may eventually permit the solution of this problem.

. What is not available.

- No completely accepted results on effects of exploding artillery munitions on dismounted troops.

- No suppression data for exploding small arms (BUSHMASTER).

- No data on suppressive effects of any types of munitions on mounted armored forces.

- No data on suppression effects of any type of munitions on aircraft.

- No data on suppression effects of large caliber direct fire non-exploding munitions.

If suppression is to be properly evaluated in the assessment of Army

forces and systems, a comprehensive program leading to development of necessary data should be established. Recognizing the significance of the gap, the initial program could well be quite aggregated and subjective. A progressive refinement of quantitative information would then occur, with those areas deemed to have the highest priority receiving the earliest attention and greatest stress. The remaining portion of this discussion outlines how such a program might be established and implemented.

- At figure 1 are a set of parameters needed to initiate the program - in this illustration, functions, distance from FEBA, other variables and degrees of suppression. The parameters may be changed for the final program - these are for illustration only.

- The remainder of the program is based on developing and then filling in a set of matrices which described the suppressive effect on a particular system in each of the varied conditions of interest. Figure 2 shows such a matrix, based on the parameters identified in figure 1.

- Figure 3 shows the matrix filled out for one set of parameters - in the case for the M60A3 tank attacking on a clear day. The effects of all types of fire - direct, indirect and a mix are shown. Since this is the initial version of the matrix, the subjective aggregated suppression effects shown in figure 1 are used. Experimentation and research may be used to broaden the categories (recall that there are 7 in ASARS) and to refine the amount of suppression suffered under each condition. It apprears that the most serious effects from suppression occur in the close-in battle; therefore of the areas on this meeting this is the one which should receive primary attention with the aim of better quantifying the effects of suppression, and in addition quantify the amount of degradation in performance associated with a particular suppression effect. As indicated in note 7, in the assault suppression may be difficult to describe or quantify, while it probably does not exist for the defender.

- Figure 4 expands examination of the MA60A3 tank to a defenseive posture. Again the close in battle appears to require the most attention.

- A "library" of suppression effects for all systems, units, and functions of interest in all significant environments should be developed in similar fashion. Figure 5 gives an illustration of the "books" in the "library". Over time this library should be extensive enough to permit consideration of suppression in all analysis. The library would include the following steps:

  - Development of each "book" based on available data plus subjective evaluation.

  - Conduct of research and experimentation to better quantify and refine each "book".

  - Incorporation of the new data into the appropriate "book".

- Figure six shows the conclusion of Work Group I. It indicated the direction to be taken in development of a suppression program.

WORK GROUP I - SUPPRESSION VARIABLES (EFFECTS)

- Following shows the units on individual functions which will be considered:

A. Command and control.

B. Target acquisition.

C. Movement.

D. Firepower.

- Battlefield is divided into three bands based on distance from FEBA, as follows:

Long Range Battle - 2000 to 3000 + meters.

Close-in Battle - 2000 to 500 meters.

Assault - 500m to FEBA.

- Each weapon system/unit/or variable will have its own suppression factors. Examples of variables:

- type weapon or vehicles
- weather
- terrain
- formation
- length of suppression

- Degree of suppression is as follows:

X not applicable.

0 no effect.

-1 slight effect.

-2 great effect.

Figure 1.

SUPPRESSION EFFECT LEVELS

	Indirect	Direct	Mix
Long Range Battle 2000 to 3000 + M			
Close in 2000M to 500M			
Assault 500 to FEBA			

Figure 2.

SUPPRESSION EFFECT LEVELS

WEATHER:

FOR

CLEAR DAY

M60A3 TANK CO

ATTACKER

	Indirect	Direct	Mix
Long Range Battle - 3000+ to 2000M	1 -2A,-1B,-1C,XD (buttoned up) -------------- FASCAM ØA, -1B,-2C,XD	2 ATGM,-ØA,ØB, -1C,XD Tank X	3 General Degradation -2A,-2B,-2C,XD Synergistic effect exist but not acct for
Close in Battle 2000M to 500M	4 -2A,-1B,-1C, -1D (buttoned up) -------------- FASCAM -1A, -1B,-2C,-1D	5 ATGM-1A,-1B, -1C,-1D Tanks ØA,ØB, -1C,ØD	6 -2A,-2B,-2C,-2D Synergistic effect exist but not accounted for
7 ASSAULT 500 to FEBA	6 ØA,ØB,ØC,ØD	6 ØA,ØB,ØC,ØD	6 ØA,ØB,ØC,ØD

NOTES:

1. Minimum kills of attacker except for FASCAM.
2. Some casualties to attacker.
3. A significant number of attackers killed considering range.
4. Increasing casualties.
5. Many casualties, but unit is now willing to take some risks to accomplish mission.
6. Heavy casualties.
7. While an attacking unit in the assault may not be "suppressed" as discussed in other areas an attacking unit which is "stopped" or "pinned down" may be considered to be suppressed. This condition is usually the result of direct fire.

CAPACITY TO BE VOLUNTARILY OR INVOLUNTARILY SUPPRESSED

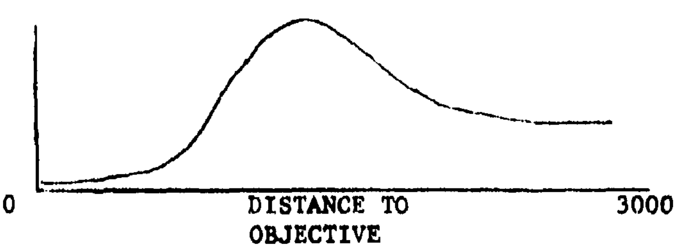


Figure 3.

SUPPRESSION EFFECT LEVELS

WEATHER: CLEAR DAY

M60A3 TANK COMPANY

	ATTACKER			DEFENDER		
	INDIRECT	DIRECT	MIX	INDIRECT	DIRECT	MIX
LONG RANGE 2000–3000 + M	(1) -2A, -1B, -2C, XD BUTTONED UP FASCAM ØA, -1B, -2C, XD	(2) ATGM ØA, -ØB, -1C, XD TANK X	(3) GENERAL DEGRADIATION -2A, -2B, -2C, XD SYNERGISTIC EFFECTS EXIST BUT NOT ACCT FOR	-2A, -2B, XC, XD FASCAM X-	ØA, -1B, XC, XD	-2A, 2B, XC, XD SYNERGISM AS FOR ATTACK
CLOSE IN 500 - 2000M	(4) -2A, -1B, -1C, -1D BUTTONED UP FASCAM -1A, -1B, -2C, -1D	(5) ATGM -1A, -1B, -1C, -1D TANK ØA, ØB, -1C, ØD	(6) -2A, -2B, -2C, -2D SYNERGISTIC EFFECTS EXIST BUT NOT ACCT FOR	-2A, -2B, XC, -1D	-2A, -2B, XC, -1D	-2A, -2B, XC, -1D SYNERGISM AS FOR ATTACK
(7) ASSAULT 500 - FEBA	(6) ØA, ØB, ØC. ØD	(6) ØA, ØB, ØC, ØD	(6) ØA, ØB, ØC, ØD	SAME AS FOR ATTACKER	SAME AS FOR ATTACKER	SAME AS FOR ATTACKER

FOOTNOTES:

(1) MINIMUM KILL OF ATTACKER EXCEPT FOR FASCAM.
(2) SOME CASUALTIES TO ATTACKER.
(3) SIGNIFICANT NUMBER OF CASUALTIES FOR RANGE.
(4) INCREASING CASUALTIES.
(5) MANY CASUALTIES, BUT TAKING ACTION TOWARDS ACCOMPLISHING MISSION.
(6) HEAVY CASUALTIES.
(7) AN ATTACKING UNIT IN THE ASSAULT MAY NOT BE "SUPPRESSED" IN THE USUAL SENSE, BUT AN ATTACKING UNIT WHICH HAS BEEN "STOPPED" OR "PINNED DOWN" MAY BE CONSIDERED TO BE SUPPRESSED. THIS CONDITION IS THE RESULT OF DIRECT FIRE.

Figure 4.

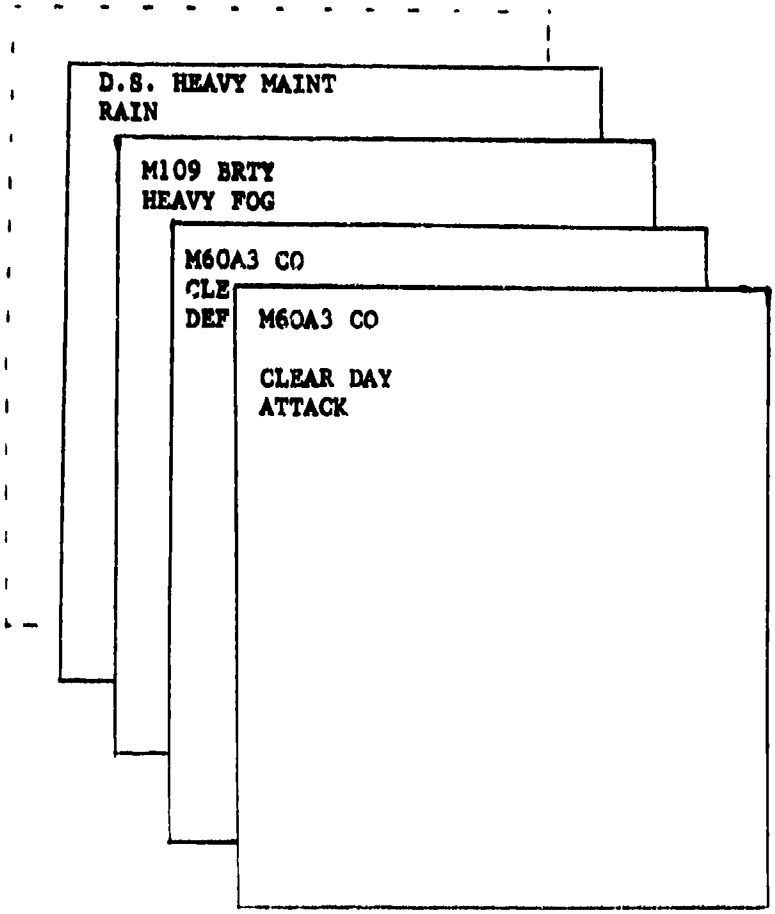

D.S. HEAVY MAINT
RAIN
M109 BRTY
HEAVY FOG
M60A3 CO
CLE
DEF
M60A3 CO
CLEAR DAY
ATTACK

Figure 5.

CONCLUSIONS

1. A matrix of systems/units vs. stimuli of significance to combat should be developed.

2. Each call in the matrix should be expanded into a library of suppression effects on system/unit functions.

3. Research, test and experiments should be stressed as a program to develop the quantitative inputs needed by each "book" in the library.

4. Emphasis should be placed on protected systems. Suppression of these systems does not seem to have been adequately addressed.

5. For dismounted elements, increased attention should be placed on rear area combat support and combat service support units.

6. Although suppression is assessed on individuals, the cumulative effect of suppression of individuals may be a degradation of unit performance which is synergistic.

7. Duration of suppression must be determined on a unit/individual basis - continued suppression may permanently degrade individual, and, therefore, unit effectiveness.

8. The conditions existing on the assault phase of combat present different problems and may make suppression of less significance than other phases.

9. Training, manning, and redundancy are essential to reduce the impact of suppression on unit performance.

10. In assessing unit/individual suppression effects, attention must be given to differences in physical vulnerabilities of crew members, e.g., M109 Chief of Section inside Howitzer vs. Ammo Handler dismounted. (Relate interaction this factor w/conclusion #6.)

<u>Figure 6.</u>

B. Group II: Suppression Variables (Causes)

Members: Mr. Hardison - Group Leader
Colonel Crawford, TSM Smoke
Lieutenant Colonel Stokes, USA Inst Environ Medicine
Dr. Burleson, TRASANA
Mr. Garrett, AMSAA
Mr. Landry, SPC
Mr. Lynch, Boeing Aerospace
Colonel Lamons, TRADOC/USAFAS Representative
Mr. C. R. Holt, Mitre Corp

In order to focus its effort Group II had the following goals and questions/issues:

1. Goals:

   a. Identify significant variables

   b. Prioritize their importance

2. Questions/Issues:

   a. What are the critical parameters/signatures? (Rate of fire/volume of fire/weight of ordnance/blast/spacial variables)

   b. What is the suppressive effect of smoke/dust?

   c. What are psychological factors?

   d. What are physical factors?

   e. What are the critical thresholds to trigger suppression?

THE GROUP II REPORT

SLIDE #1

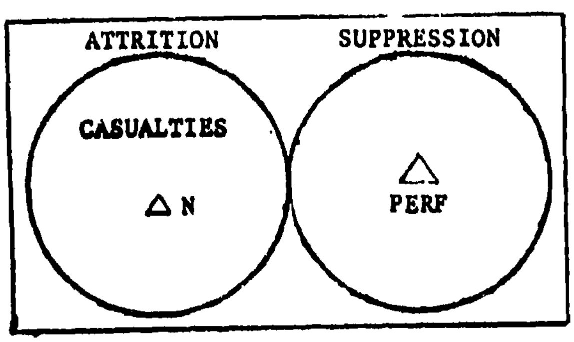
SUMMARY

- OUR THINKING FUZZY
- BUT WE ARE THINKING
- WITHIN & BEYOND CHARTER
- PROBABLY REDUNDANT TO OTHERS IN PART
- WE'RE NOT CONVINCED THAT NOTHING CAN BE DONE
- OUR PARTIALLY FORMED IDEAS ARE SHAREABLE.

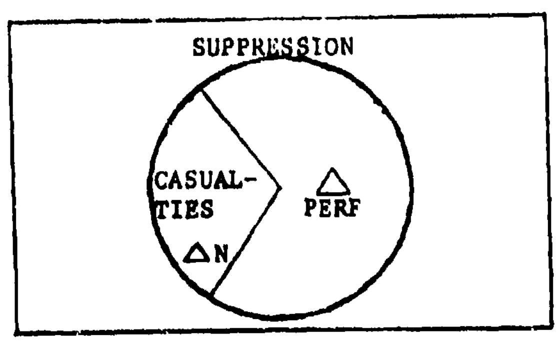
SLIDE #2

WORKING GROUP 2 CONVENTION

THIS



NOT THIS



SLIDE #3

<u>DOMAINS WHICH WE SUSPECT TO BE IMPORTANT</u>

- SPACIAL - PROXIMITY OF EFFECT TO SUPPRESSEE
- TEMPORAL - NR. OF EFFECTS PER UNIT, TIME DURATION
- MAGNITUDE - SIZE OF THE STIMULI
- EXPERIENCE - HISTORY OF THE SUPPRESSEE
- BEHAVIOR OPTIONS - SHORT TERM RISKS & LONGER TERM RISKS
- PERCEPTION OF WELL-BEING, AND IT'S DIRECTION OF CHANGE RATE. (S.S.S.)

SLIDE #4

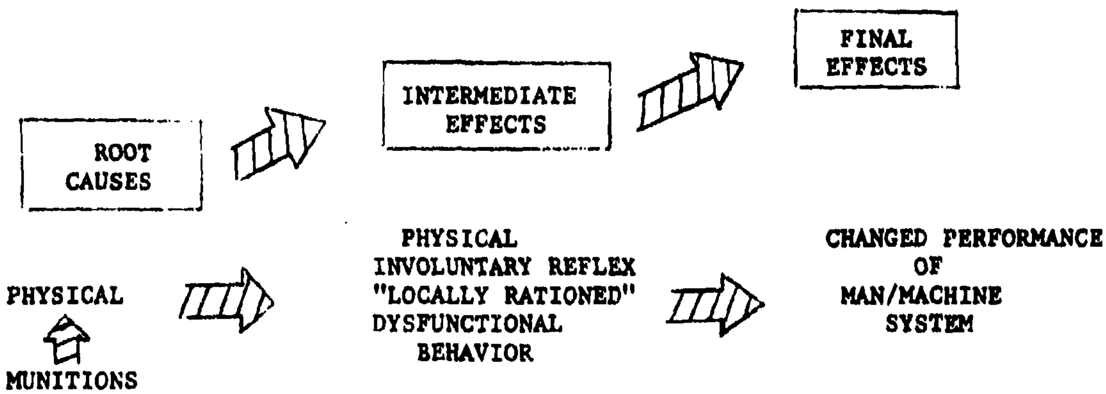
<u>SOME FIRE-INDUCED CAUSES OF SUPPRESSION</u>

- LOUD NOISES/BRIGHT FLASHES	--->	INVOLUNTARY REFLEX
- BLAST OVERPRESSURE/SEISMIC SHOCKS	>	BODY DISPLACEMENTS
- SMOKE/DUST	--->	REDUCE VISION
- THERMAL ENERGY/SHELL FRAG	--->	CONCERN FOR LIFE
- DEBRIS, EJECTA	--->	MINOR WOUNDS

<u>CHANGE</u> THINGS, PEOPLE, ENVIRONMENT, ACTIONS

SLIDE #5

THE CHAIN



SLIDE #6

OUR FAITH IS THAT

- SEVERAL OF THE PRINCIPLE ROOT CAUSES OF SUPPRESSION:
  - ARE OF A PHYSICAL NATURE
  - CAN BE IDENTIFIED AND MEASURED
  - PRODUCE PREDICTABLE/REPRODUCIBLE EFFECTS WHICH ALTER WHAT ELEMENTS OF FORCES - CAN DO
    - DO DO

- A GOOD UNDERSTANDING OF THE ABOVE, EVEN IF NOT ALL INCLUSIVE, WOULD BE A STEP IN THE RIGHT DIRECTION.

SLIDE #7

CAN SUPPORT BE SUPPRESSED?

- MOVE & DISTRIBUTE SUPPLIES	YES
- MODIFY BATTLE ENVIRONMENT (BRIDGES, BARRIERS, ETC.)	YES

SLIDE #8

CAN CONTROL BE SUPPRESSED?

- ACQ INFO RE TERRAIN WY, EN ORBAT, ENSIT, FRIENDSIT	YES
- COMMAND	YES
- COMMO	YES
- ORGANIZATION	NO
- DOCTRINE	NO
- TRAINING	NO

SLIDE #9

CAN MANEUVER BE SUPPRESSED?

- CAUSE UNWANTED MOVES (SEEK COVER)	YES
- DISSUADE WANTED MOVES	YES
- CHANGE ROUTES & RATES	YES

SLIDE #10

CAN FIRE BE SUPPRESSED?

- DIRECT & INDIRECT	YES
- POINT & AREA	YES
- S-A & S-S	YES
- UNARMORED &	YES
ARMORED	LESS YES
- HOWITZERS VS MRL	(NEEDS THOUGHT)

SLIDE #11

SO WHY NOT?

SINCE THE OPNL CONCEPT REQUIRES	USE INDIRECT FIRES
- CONTROL	- TO SUPPRESS CONTROL
- FIRE	- TO SUPPRESS FIRE
- MOVE	- TO SUPPRESS MOVEMENT
- SPT	- TO SUPPRESS SPT

NOTION: USE FIRES TO COUNTER ENEMIES ABILITIES TO ACCOMPLISH THE SEVERAL FUNCTIONS, NOT JUST VS MAN UNITS & FS ELMTS.

SLIDE #12

A THOUGHT FRAMEWORK

CONTROL

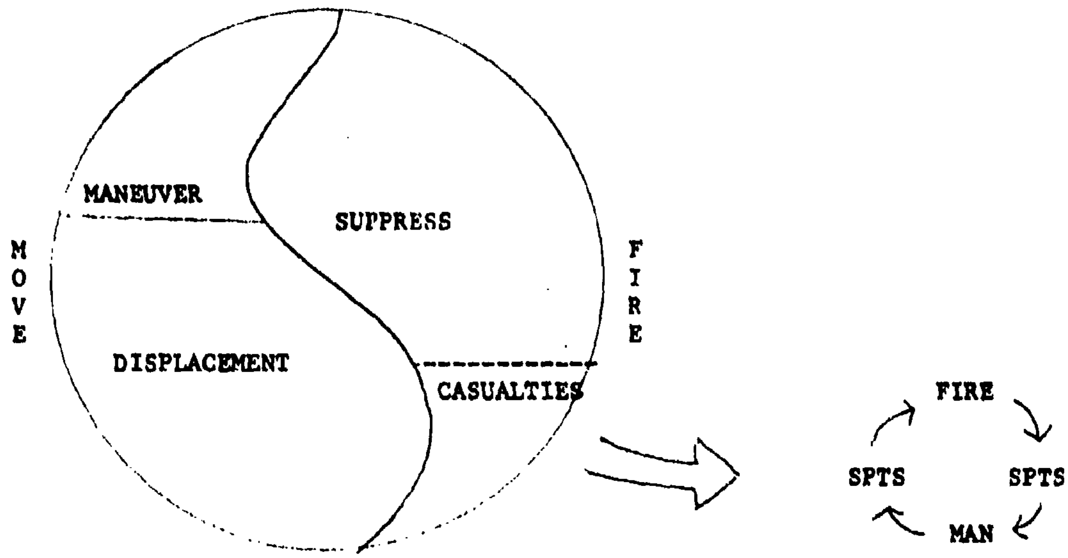
FIRE

MOVE

SUPPORT

SLIDE #13

A COMMON PERCEPTION



SLIDE #14

WE INTUIT THAT

- WERE OTHER THINGS ABOUT EQUAL, WE WOULD USUALLY PREFER ATTRITION TO MERE SUPPRESSION, BECAUSE ATTRITION IS MORE LASTING
- <u>HOWEVER</u> IT SOMETIMES MAY BE FAR MORE POSSIBLE AND LESS EXPENSIVE TO SUPPRESS THAN TO KILL
- <u>MOREOVER</u>, THOUGH LESS FINAL THAN ATTRITION, SUPPRESSION WILL OCCUR AND IT STILL MAY CONTRIBUTE GREATLY TO OUTCOMES OF COMBINED ARMS & SPT OPNS - SO A GOOD BARGAIN AT THE PRICE (CONSIDERING ALTERNATIVES)

- <u>CONCLUSION</u>: WE NEED TO UNDERSTAND SUPPRESSION

SLIDE #15

IN OUR VIEWS

- SUPPRESSION

  - CAUSES)

  - DISSUADE)

  - DISRUPTS) ENEMY ACTIONS

  - DEGRADES)

  - PRECLUDES)

- SUPPRESSION EFFECTS TEND TO DECAY OVER TIME BUT ARE RENEWABLE

SLIDE #16

INDIRECT FIRES PRODUCE

- ATTRITION - CHANGES IN THE NUMBER OF ELEMENTS WHICH CONTINUE TO EXIST IN A FORCE

--AND--

- SUPPRESSION - CHANGES WHAT THE ELEMENTS OF A FORCE:

  - CAN DO
  - DO

- (IMPORTANT TO KEEP GOOD BOOK ON BOTH)

  (MAXIMIZE BENEFIT OF FIRES, CONSIDERING BOTH)

SLIDE #17

A RANDOM THOUGHT

FACT: ARMY SYSTEMS ARE EMBEDDED - e.g. SUB-ITEMS IN ITEMS IN UNITS IN ORGANIZATIONS IN FORCES.

RESULTS: SUPPRESSION OF A SYSTEM OCCURS WHEN A NEXT LOWER SYSTEM IS A CASUALTY; CASUALTY OF A SYSTEM PRODUCES SUPPRESSION OF THE NEXT HIGHER SYSTEM

SLIDE #18

FINALLY

- IT'S ALL MERELY "TERMINAL BALLISTICS"

- WHEN THERE WAS AN ORDNANCE CORP, THERE WERE PEOPLE WHO KNEW OR WERE LEARNING THESE THINGS
- BUT NOW ......

AD HOC WON'T HACK IT -

C. Group III: Data Base Requirements

Members: Dr. Bryson, CDEC - Group Leader
Colonel (Ret) Dupuy, TND
Captain Lawson, DNA
Mr. Cline, SPC
Mrs. Shirley, Infantry School
Mr. Brown, Boeing Aerospace
Colonel Pokorny, TRADOC/USAFAS Representative
Dr. Leake, Armor & Eng Board
Mr. Loveless, USAFAS

In order to focus its effort Group III had the following goals and questions/issues:

1. Goals:

a. Data source list

b. Priority of required testing

c. Recommended experimental approach

s. Questions/Issues:

a. What data is available?

b. What are other likely sources?

c. What data gaps remain?

d. What experimentation/testing is needed?

e. How should the experiments be designed?

THE WORK GROUP III REPORT

1. What sources of data are available?

There are two prime sources of data available. They are : 1) historical; and 2) experimental.

1) A prime source of historical data is British or Operations Research in Northwest Europe. A team with the 21st Artillery Group accumulated much data on bombarding German troops in NW Europe. SLA Marshall held post-combat interviews with soldiers in order to get a handle on suppression.

2) For experimental data CDEC has data from the following tests on suppression: DUCS, DACTS, SAGE, SUPEX and SUPEX III. The USAARENBD has data from the Tank Company Night Fight Team and TTS OT II. It will also provide additional data from the Crewman's Vehicle Reference Header Test which will occur in the November 1979 timeframe. HEL also has data on the effect of noise on the ability of a gunner to track a target. Dollord & Miller's, Personality Theory, McGraw-Hill gives a psychological understanding of fear in terms of the gradient of avoidance and provides other references.

The results of the experimental data provide insights into the ability of the suppressee to shoot, move, communicate and acquire targets.

What needs to be done is to connect the experimental data to the historical data which is a much greater and ample source.

2. What are other likely sources?

There is a wealth of historical data that needs to be sorted and organized. There is also a possibility of additional experiments being conducted to establish the relevance of this data as well as to fill any gaps that presently exist.

Some of the sources or other likely sources are:

1) Questionnaires; 2) interviews; 3) police reports; 4) FAA pilot reaction in time and 5) psychological studies of animals under extreme stress.

3. In considering factors affecting suppression (see attached list), it seemed that three nearly independent, somewhat exhaustive factors were:

1) Type/mission of suppressed unit

2) Immediate relationship of suppressed unit to enemy elements

3) Perceived lethality of suppressive fire

Taken in reverse order, data gaps and experimentation needs are as follows:

PERCEIVED LETHALITY:

- most data currently available

- need duration of suppression data

IMMEDIATE THREAT

- need data on behavior of suppressee under constant stimulus as a function of immediate threat of his targets

TYPE UNIT

- need data on differential behavior as a function of whether unit is

  --indirect fire unit

  --armor unit

  --dismounted infantry

  --mounted infantry

  --other unit

4. Given that a unit is suppressed P(%), what is the degradation of its ability to ____________________ (as a function of time)?

- The most important activity to complete the sentence is "shoot"

- Except for the interdiction mission, the activities of move, communicate, and acquire targets are secondary

- Experiments are needed to answer this question

NOTE: It proved useful to the group to think in terms of the following desired results for degrading the enemy force:

1) Damage or disrupt systems

2) Impact on Human Factors

3) Change the Environment

Fire suppression addresses the second item.

FACTORS AFFECTING SUPPRESSION

I. WEAPONS FIRE CHARACTERISTICS:

Volume of Fire Per Unit Time

Cyclic Rate Per Burst

Duration of Fire

Acoustic Signature

Acoustic Tone

Accuracy of Fire

Perceived Lethality of Projectiles

Distance of Passing or Impacting Projectiles from the Soldier

Manner of Distribution of Fire

Coordination of Fire with Suppressive Fire from Other Types of Weapons

Weapon's Basic Load

Visual Cues

Uniqueness of Sound (e.g., ability of enemy to consistently identify the sound with a particular weapon)

Actual Lethality of Projectiles

Signature Cues at the Weapon (e.g., muzzle blast)

In Flight Visibility of Projectiles (e.g., tracer)

Impact Signature (e.g., debris or dust thrown up by impacting rounds)

Time to Reload

Reliability

Fuzing

Primary Determinants:

Proximity of Incoming Rounds to the Individual

Loudness of the Projectile Signature

Volume of Incoming Rounds to the Individual

Type of Weapons Systems Employed Against the Individual

Unique Projectile or Weapons System Signature

Visual and Auditory Signature Associated with Impact of the Projectile

III. OTHER FACTORS

Experience Under Fire

Leadership of the Unit

Fatigue/Stress

Environmental Factors (climate, weather, terrain, night OPS)

Hunger

Training

Doctrine

Posture

Task Loading

Unit Morale

Level of Unit Casualties

Availability of Cover and Concealment

Distance from Enemy

Group Dynamics (e.g., social stimuli of other soldiers, NCOs, officers)

Religious values

Mission type

Proximity to Other Unit Members, Commander, Automatic Weapons

Awareness of Enemy Fires

SLIDE #1

QUESTION

WHAT IS IT THAT I DO NOT KNOW, THAT I WOULD LIKE TO KNOW, THAT I CAN FIND OUT FROM:

- ANALYSIS?
- HISTORICAL SOURCES?
- EXPERIMENTATION?

SLIDE #2

TO DEGRADE THE EFFECTIVENESS OF AN ENEMY FORCE, ONE CAN:

- DAMAGE OR DISRUPT SYSTEMS
- CHANGE ENVIRONMENT
- OTHERWISE ALTER HUMAN BEHAVIOR

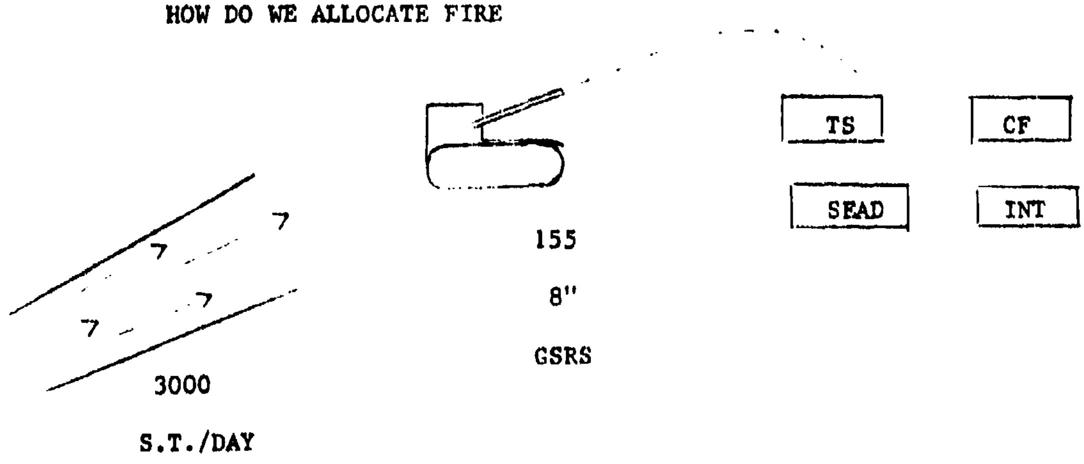
SLIDE #3

FACTORS AFFECTING SUPPRESSION

1. TYPE OF UNIT/MISSION OF UNIT
2. PROXIMITY OF ENEMY
3. PERCEIVED LETHALITY

SLIDE #4

HOW DO WE ALLOCATE FIRE



SLIDE #5

GIVEN THAT A UNIT IS SUPPRESSED P%, WHAT IS THE DEGRADATION OF THAT UNIT'S ABILITY TO:

- SHOOT
- COMMUNICATE
- MOVE
- ACQUIRE TARGETS

AS A FUNCTION OF TIME?

SLIDE #6

SPECIFIC QUESTIONS WHICH MAY BE ANSWERED BY HISTORICAL OR EXPERIMENTAL DATA

WHAT IS THE NATURE OF SUPPRESSIVE FIRE REQUIRED TO FORCE:

A TANK CREW TO BUTTON-UP?

AN ARTILLERY BATTERY TO CEASE FIRE?

AN AD UNIT TO CEASE FIRE?

AN INFANTRY UNIT TO CEASE FIRE?

AN INTERRUPTION OF TARGET ACQUISITION?

AN INTERRUPTION OF COMMUNICATION?

AN INTERRUPTION OF LOGISTICS ACTIVITIES?

SLIDE #7

SUMMARY OF ADDITIONAL DATA NEEDED

- DURATION OF SUPPRESSION UNDER VARIOUS CONDITIONS

- FOR FIXED PERCEIVED LETHALITY, PROBABILITY AND DURATION OF SUPPRESSION AS A FUNCTION OF:

  → TYPE UNIT

  → MISSION

  → PROXIMITY OF ENEMY

D. Group IV: Suppression Modeling

Members: Dr. Payne - Group Leader
Colonel Reed, CAC
Captain (P) Wallace, Fort Knox
Dr. Dubin, AMSAA
Mr. Gividan, ARI
Mr. Weiss, Litton
Dr. Blum, Vector Research
Colonel Slater, TRADOC/USAFAS Representative
Mr. Porreca, R&D Associates
Mr. Thorp, TRASANA
Mr. Millspaugh, USAFAS

In order to focus its effort Group IV had the following goals and questions/issues:

1. Goals:

a. Agreement/consensus on the current modeling

b. Agreement on approaches for improvement

2. Questions/Issues:

a. Review current/past methodologies.

b. Review what development is on-going.

c. What are the gaps?

d. What approaches are the best now and in the future?

3. Because of the diversity of the manner in which the work of Group IV was recorded, and in order not to inadvertently edit out significant information, the report of Group IV will be presented in four parts:

a. First day summary

b. Dialogue on the second day

c. Summary presented to Symposium participants

d. Chairman's Post - Symposium Summary

The Work Group IV Report: Part a

1. Introduction by Dr. Payne concluded that if we had reports from Groups I and II, modeling would then be a simple process.

2. Our current models have sufficient mathematical flexibility to represent the small body of data available to us now.

3. Discussion on definitions resulted in essentially the same definition that was presented in the opening meeting.

4. Discussion on types of models.

   a. Models for process control.

      Should we create model for this and do we need to determine tactics or weapons design? Consensus was that we do not want a process control model.

5. Discussion concerning characteristics of current models which evolved into discussion of various tactics. Group concluded that suppression effects are scenario dependent.

6. Discussion of perceived threat/danger versus perceived benefit of action e.g. volume of fire makes a big difference and casualties in vicinity spur individual to move. Models that account for effects are efficient because we are not apt to obtain additional data.

   Example: We can describe

   Flinching

   Interfering

   Inhibiting

   Neutralizing

   Due to equipment choices

   position choices

   time choices

   target choices

   reorganization choices

   and in anticipation of subsequent action

7. Physical posture of elements in target area affect detection, degrade P_H and P_K and inhibit ability to shoot or move.

Also - suppressing 100% of unit for 50% of the time is entirely different from suppressing 50% of the unit for 100% of the time. Models do not always make the distinction.

8. The discussions of the foregoing topics ranged widely and many diverse opinions were voiced. However, the group generally agreed on the following:

a. Suppression is certainly important enough to be modeled.

b. Suppressive effects may be as important as lethal effects.

c. Suppression is caused by a wide diversity of variables and is difficult to model explicitly.

d. Generally that which has a greater potential to kill has greater potential to suppress, with two notable historical exceptions, white phosphorus and the "Headlight" round for WWII bombers.

e. Artillery bombardment almost completely eliminates return fire by infantry from the beaten zone.

f. Artillery will probably cause tanks to button up and move out.

The Work Group IV Report: Part b

On the morning of the second day (third session) a portion of the discussion was recorded in writing; and, simultaneously, the names of the primary participants were given. Their names appear below followed by the dialogue:

1. GEN (Ret) William Depuy
2. Dr. Robert Blum
3. Dr. Henry Dubin
4. Dr. Wilbur Payne
5. COL Robert Reed
6. Mr. Keith Thorp

Dialogue

Depuy: Historical perspective on suppression. US failure to grapple with the real problem - that is getting fire on the target when the ground attack begins. When the suppression is needed most - all fire ceases. This is one thing modeling does not address sufficiently. At Monte Casino the Germans had 3 - 5 min after British prep ended to get into position.

Payne: Models have the capability. The problem exists with the tactical approach taken by the players/programs.
Perhaps we need to deal with activities and consequences of activities dealing with exploitation of suppression.

Depuy: The Germans prepped with small amounts of artillery, then heavy weapon direct fire, and finally with small arms - suppression. US approach was heavy artillery - lull - then attack (large groups of targets). Israelies will not attack with their tanks until they have destroyed all visual enemy tanks or suppressed or driven them off. Can models reflect that?

Payne: Yes — it depends on the scenario presented by armor types. One of the problems is modeling the time after suppression. The Russians' model intiial go to ground time then all the rest is reorganization time.

Depuy: Difference exists between prepared position and hasty position reaction to suppression.

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Payne: Yes -- it depends on the scenario presented by armor types. One of the problems is modeling the time after suppression. The Russians' model intiial go to ground time then all the rest is reorganization time.

Depuy: Difference exists between prepared position and hasty position reaction to suppression.

Payne: Models do handle this although perhaps incorrectly. Going beyond this may cause users to look too closely at details. The correlation exists between lethality and suppressiveness. It may lead to problems to compensate for the variations to that rule.

Dubin: What General Depuy may be telling us is that we do not address the tactics of suppression.

Payne: Again this is a function of the tacticians using the models.

Depuy: Models should also handle performance of crews.

Payne: People are not comfortable with projections of less than outstanding performance. Any model is capable of doing this.

Dubin: The biggest criticism in our last games is that there is too much attrition for rounds expended.

Reed: Models need to better address how much degradation results.

Thorp: Models need to address continued suppression. Times/Amount Ammo.

Payne: Some models do that (ASSARS, etc.)

Thorp: Is allowing .hat capability worthwhile?

Payne: Transition states are infrequent.

Reed: General Dupuy may be looking for a process control model to explore tactics.

Payne: Every means of enhancing suppressive effects, degrades lethal

effects. Suggest two level board to review proposals - one to review effects, one to decide if it is cost effective. Models can't answer that question.

Payne: Almost any round will produce flinch. Bigger rounds produce longer effects. Models don't represent neutralization (from long duration, saturation explosives).

Reed: What about Nukes? Delays casualties, unit dissolution, suppression on grand scale.

Dubin: Chemical weapons also?

Reed; Psycho/Physio effects - heat injury?

Payne: We have difficulty isolating suppression. Different results from proving ground and combat involve many factors. May be double-dipping in trying to solve this problem.

Dubin: Great deal of bureaucratic pressure to reduce rate of attrition, and speed. Suppression is a straw we are grasping for.

Payne: Will use suppression to label effects which we cannot effectively factor. Our models are throughput models - if you put it in at one end, they come out at the other.

Blum: Models do not include conditioning variables.

Payne: I feel it is better with the current system. Player inputs behavior.

Blum: Agree.

Use as a surrogate to conditioning variables (state variables).

The inputs of the players.

Conditioning Variables for Suppression:

1. Backgrounds
   a. Audio
   b. Visual
   c. Duration
2. Command and Control Function
3. Conditioning variables for aggregated models.

Payne: We have not answered the question raised by Dr. Dubin with regard to model pace VS battle pace.

SUMMARY - This session was spent discussing the need for suppression modeling, problems involved and capabilities of existing models to incorporate both differing tactics and suppressive effects.

The military needs for suppression were provided in large part by General (Ret) Depuy through discussion of WWII experience and Israeli use of suppressive and lethal fire prior to armored attacks. His questions to the group were primarily of the model's capabilities to examine these tactics and effects.

Answers to his questions were given primarily by Dr. Payne who stated that Depuy's desires could be met with existing models by proper use of tactical decisions and selection of scenarics to be played.

Most of the problems surfaced during this session dealt with difficulty in obtaining data and the degree of detail that should be incorporated into the models.

A driving problem from AMSAA's viewpoint is the need to provide effects internal to the models that reduce rate of attrition and speed of the battle. It is their experience that almost all games progress at speeds and attrition rates much higher than real life based on history.

Questions were posed regarding the inclusion of suppression in models of nuclear games such as DIVWAG at Sandia Labs. No conclusions regarding this were reached.

The group adjourned at 1000 hours arriving at the same conclusions reached the previous afternoon.

The Work Group IV Report: Part c

Slide #1

QUESTIONS AND ISSUES

1. Review current/past methodologies.

2. Review what development is ongoing.

3. What are the gaps?

4. What approaches are the best now and in the future?

Slide #2

MODEL TYPES

1. Models that account for effects.

2. Models for process control:

   a. Tactics

   b. Weapon design

MODELING APPROACHES

1. Hypothesize a particular action in response to risk, predict effect on perfomrance.

2. Predict effect on performance with no specification of action.

Slide #3

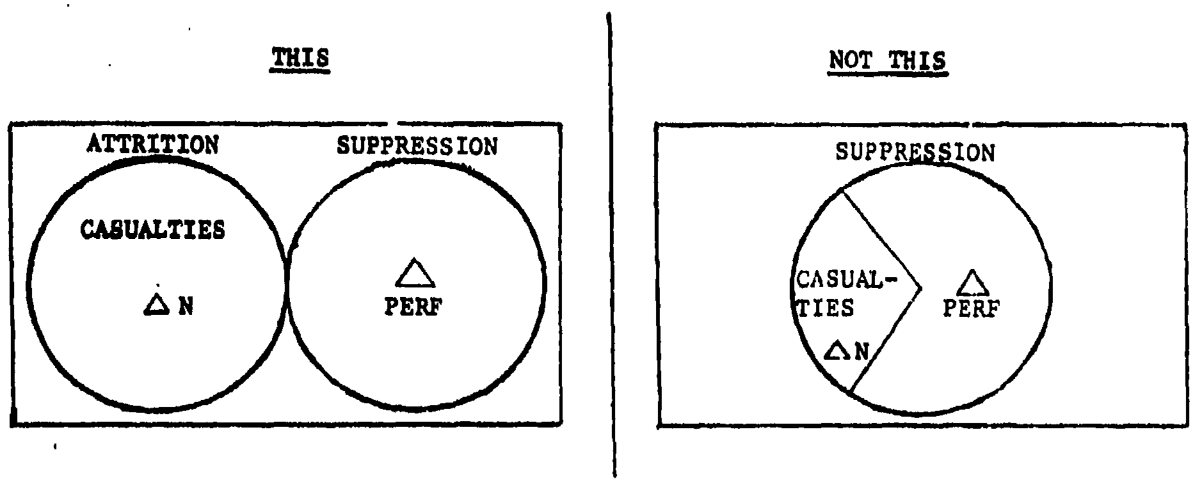
CURRENT/PAST METHODOLOGIES

- Almost all are attempts to account for effects, predict performance without specifying action.

- Can build and occasionally use model approach 2.

Slide #4

WORKING GROUP 2 CONVENTION



Slide #5

IN THE SMALL	IN THE LARGE
Flinching	Equipment choices
Interfering	Positioning choices
Inhibiting	Time choices
Neutralizing	Target choices
Due to -	Reorganization choices
	in anticipation of -

The Work Group IV Report: Part d

SUPPRESSION MODELING

Summary of Discussion in Working Group IV

1. The initial discussion centered on fundamentally different types of models. That is models that differ in purpose or in the type of problem to be investigated. In the terms used by the working group these were described as Models for Process Control and Models for Representing Suppressive Effects.

a. Models for Process Control.

(1) This term was used to describe models that might be used either for weapon system design trade-off purposes or perhaps for qualitative requirements purposes.

(2) For example, it is possible that specific design features of weapons or munitions could enhance their suppressive effect. If there were reason to believe this and if such features could be added with neither penalty in the lethal effects or added cost, there would, of course, be no need for either model or analysis. However, the perversity of nature makes it almost certain that, even if we knew how to design weapons with assurance that their suppressive effect would be enhanced, we would face tradeoffs of lethal effects or increases in cost.

(3) There is some evidence in or on the fringes of history that suggest that suppressive effects may not be directly and tightly

coupled with lethal effect. Further, there are some suggestions that weapons with a high suppressive potential might yield greater benefit in some uses than more lethal weapons with lower suppression potential.

(a) Cases of this that were cited as probable evidence from history included the steady increase in the use of White Phosphorous in final protective fire during WW II. This has generally been explained in terms of the suppresive benefits of the smoke and of an apparently deep seated fear of burning. The Headlight round (a .50 caliber round used in B-17's that was modified so the tracer was highly visible to the target) was also discussed. It was noted that some people attribute the universal trend toward automatic rifles as an example. There is some reason to believe that automatic rifles will in fact and predictably produce fewer casualties than aimed fire from semiautomatic rifles. But there is also some evidence that units armed with semiautomatic rifles are less likely to engage when faced with automatic fire.

(b) It is clear in the literature that some people believe that mixes of bomblets and mines or of instant and delayed fuzed bomblets would have more total effect than would rounds that contain only instant fuzes even though current models show these would have lower expected lethal effect than the same weight of instant fuzed bomblets.

(4) In the end, perhaps because the composition of the group did not include weapon design engineers, there was an apparent consensus that there was little interest in models of process control.

Even those members who thought such models would be useful if available did not see a clear path to their development. That is, neither further review of history nor feasible peacetime experiments are likely to produce a semiquantitative basis for relating particular design features to specific enhancements of suppressive effect.

(5) If these views are correct then a model that purported to be a process control model would, in the end, rest on assumptions that connect cause and effect, and would not be different from models designed solely to represent effects.

(6) If there is management interest in this class of problems, they could be approached, in the absence of process control models, in a more direct if judgmental manner. For example, a board could be created to review specific weapon design proposals. If this board judged the specific proposal would produce some enhanced suppressive effect a second board could explore and render judgment on whether the benefit achieved from this would outweigh the penalty in lethal effects or costs. If either board could hypothesize the suppression enhancement in specific terms this could, of course, be investigated in models designed to represent effects. As CG TRADOC, GEN DePuy initiated the most recent round of renewed interest in suppression through the SUPEX experiments. His discussion with the group indicated his interest was to make sure that the effects of suppression were not ignored.

b. Models for Representing Effects.

(1) The group generally agreed that in addition to their potential to kill and damage, weapons do indeed have less direct effects embodied in the working definition of suppression. Further, these effects are generally too large to ignore and in many cases may be as, or more important in combat than the damage producing effects. Because of this and in spite of our limited historical or empirical knowledge, there was general agreement that the effects should not be ignored in models of combat.

(2) It was clear partly from the briefings in the general session and partly from the knowledge of members of Working Group IV that the most detailed of the current family of combat models have an elaborate and flexible representation of suppressive effects. Even the analytical and rather abstract models can represent assumptions about suppressive effects. At the least, rates of target detection and of fire are explicit or implicit inputs to most models and these can be judiciously chosen to represent whatever the user believes about suppression.

(3) The present models seem able to represent the suppressive effects of fire as these are described in both historical and empirical sources. They do not, however, usually represent all of the potential effects in their day-to-day use in various studies.

(a) Generally speaking, the current Monte Carlo models accumulate information over time about the number and type of rounds landing in the vicinity of combat elements. If the element is not killed by the fire the models then associate a change in posture and/or of activity of the element as the suppressive effect. In particular an element may disappear as a direct fire target and may simultaneously have reduced capability both as a detector of targets and in firing on them.

(b) In most such models the different types of arriving rounds have different weights or suppression indices. Similarly, to one degree or another, it is generally true that the suppressive effect of close misses is greater than more distant ones.

(4) These are not the only "suppressive" effects that are or can be represented in current models.

(a) The working definition of suppression proposed in the general session would include the effects of smoke and dust in so far as they affect vision or coordination as "suppressive" effects. There is a large experimental program covering at least the vision related effects of smoke and dust. The present models are rapidly changing to exploit the results of this investigation.

(b) The group hypothesized and named several different effects that might represent a subdivision of the broad phenomenon into sub classes. These were classified into two different categories.

1 Actions taken as a result of receiving fire.

a Flinching. A term used to describe a largely involuntary, instantaneous reaction to the noise or flash of a round. Generally believed to be of short duration this can nevertheless interfere with immediate on going tasks such as aiming or controlling weapons. This is not usually represented as a separate phenomenon in combat models.

b Inhibiting. A term used to describe a more or less conscious and controlled action to reduce exposure to a risk from fire. This term was used for actions such as taking cover or changing the state of movement. To varying degrees present models represent this.

c Neutralizing. This term was used to represent what appears as a very long term psychological effect of fire. The principal historical source for this is the final report of Operational Research Section 2. But there are other historical examples that indicate it is a real phenomenon. It is not represented in current, small unit combat models. The volume-duration dimensions of fire that occurs in such models seldom, if ever, reaches the range in which this phenomenon seems to occur.

d Interfering. This term was used to represent effects where, independent of psychological state, the effects of the fire would make it impossible to continue or perform some task. This subset would then include effects of smoke or dust. Current models do not usually incorporate these effects in that part of the model called the "suppression" submodel.

2 Actions taken in anticipation of fire.

a It seemed worthwhile to note that even though these are not usually described as "suppressive" effects there are some influences from the threat of fire that are at least implicitly represented in current models. For example, the threat of fire influences the choice of positions for elements in the scenario. It also influences the timing of certain events in the sense that a unit may be instructed not to occupy some position until after the preparatory fire phase. On a larger scale it can result in limits on resupply or support operations, for example, through a doctrine that permits supply operations only at night. It is, at least partly, anticipation of fire that leads to some equipment choices such as the APC and SP artillery.

b These effects are represented both in the input and output to present models. For example, to the extent certain otherwise desirable fighting positions are not occupied, both casualty production and casualty acceptance are affected in current models.

2. A purist might note that the difference between the two types of model is superficial. The principal sources of quantitative data for either class of models are the Final Report of ORS-2, a source that under'ies early US and present UK models, some work by Litton using sources and data from Vietnam and the Series of SUPEX experiments at CDEC. As a general observation all of these indicate (or at least do not conflict with the hypothesis) that, in the main, the suppressive effect of a given round at a given distance is closely correlated with its lethal potential. That is, considering the individual effects of

single rounds, a round with greater potential for casualty production also has greater suppressive potential. This may not be universally true and, as noted, there are some examples of probable exceptions. This relation between lethal and suppressive effect might be perfectly adequate as in present models to capture most of the effect of suppression. But so long as the exceptions remain unexplored and unexplained, it would be wrong to use the results of these for detailed weapon design purposes. It could be equally wrong, without intervening judgment, to use the results of these models for choice of tactics.

3. Generally speaking, the working group had no specific suggestions for modifying the basic structure of the best of the current combat models.

a. In every area where there is a modicum of data the models can and do use it.

b. In areas where there is nearly complete absence of data the models can accept judgmental inputs. Among such areas, it can be noted that wide differences exist in the literature and in present models or in their application about the rate of recovery from the flinching and inhibiting subclasses of suppression. Nor is it clear that present models distinguish between "flinching" and "inhibiting" effects if, indeed, there is a difference. It can also be noted that wide differences exist about suppression effects on the crews of armored vehicles and artillery units. None of the three basic sources of data deal very directly with armored and

artillery units. It can be shown that the computed results from the present models depend as much on assumptions about the duration of suppression as they do on the probability that it occurs.

c. It might be possible to narrow these differences either by bureaucratic fiat or by emerging consensus. But, in the main, it is very clear that most differences in the modeling of suppression rest on a quite real difference of opinion about the effects. Since that difference exists it is probably more useful to insist that the particular treatment of suppression be a mandatory part of study reports than it would be to impose a single standard approach to this problem.

E. Group V: Suppression/Countersuppression Combat and Training Developments

Members: Mr. Murphy, SAI - Group Leader
Major Graham, Infantry School
Major Money, Fort Rucker
Captain Gunderson, AMSAA
Lieutenant Colonel Bacon, TSM Smoke
Colonel Quinlan, TRADOC/USAFAS Representative
Major Johnston, Fort Bliss
Major Kalla, AMSAA

In order to focus its effort Group V had the following goals and questions/issues:

1. Goals:

a. Prioritize on-going developments

b. Recommend high pay-off areas

2. Questions/Issues:

a. What combat activities are most easily suppressed?

b. What combat activities offer best pay-off for suppression?

c. How do we become less suppressible? (tactics, material, training)

d. How do we become better suppressors? (tactics, techniques, munitions, weapons)

The Group V Report

DISCUSSION:

- The definition of suppression may be adequate but the group is still examining what it means to 'suppress.' Suppression is one of the things we do to defeat the enemy. In order of increasing severity we do the following: disrupt, suppress, neutralize, destroy.

- Emphasis should be placed on the training of our troops to make them harder to suppress and to make them better suppressors, particularly in a chemical warfare/smoke environment.

QUESTIONS/ISSUES:

What combat activities are most easily suppressed?

- exposed personnel
- soft equipment
- vulnerable equipment + lack of training = easily suppressed target

What combat activities offer best pay-off for suppression?

- focus on front line units/activities
- timeliness
- armor, observation, C&C, fire support, ADA

How do we become less suppressible?

- position/equipment hardening
- shoot and scoot
- training/an understanding of deception
- laser considerations

How do we become better suppressors?

- better, more realistic training
- timeliness
- examine munition mixes, e.g., FASCAM + ICM
- training (combined arms, in degraded environment)
- SEAD: integrate efforts of USAF and Army air and ground assets

GOALS:

Prioritize ongoing developments:

- GSRS
- BUSHMASTER
- IMPROVED SMOKE*
- FIREFINDER
- FASCAM*
- IFV/CFV
- DAD-C^3
- RPV
- TACFIRE/BCS
- ARP
- COPPERHEAD
- HELFIRE
- ARTY PIP'S*
- SINCGARS
- OTHERS?

* - Priority

Recommended high pay-off areas

- maneuver
- C^3
- Fire Support

SUMMARY

"Suppression" requires definition and clarification through measurement. The time dimension is important.

Training offers leverage in improving our capability to suppress and to become less suppressable.

Appropriate munitions mixes have not been determined, nor are the implications of smoke and other forms of observation available for consideration by combat developers.

The dimension of suppression should be considered along with lethality in prioritizing hardware under combat development. While the priority may not change, the mix, doctrine, and tactics of systems will be influenced when this is placed into perspective. Emphasis should be on product improvements for the current time frame.

SECTION VI - ADDITIONAL MATERIAL

The articles in this section were submitted for consideration at the Fire Suppression Symposium, but only one article was submitted in a sufficient quantity to allow each participant to receive a copy; therefore, the seven articles are inclosed here for future consideration in studying the suppressive effects of fires on the battlefield. The titles of the articles and the names of their authors appear below.

Appendix A - A Further Look at the Prediction of Weapons Effectiveness in Suppressive Fire by Albert L. Kubala and William L. Warnick (ARI)

Appendix B - Executive Summary of SUPEX IIIB Final Report (USACDEC)

Appendix C - Indirect Fire Suppression Model by Phillip M. Allen (AMSAA)

Appendix D - Review and Evaluation of Current Suppression Models With Proposal for Interim Model by Phillip M. Allen (AMSAA)

Appendix E - Suppressive Effects of Artillery Fire by F.W. Niedenfuhr (MITRE Corporation for DARCOM)

Appendix F - Toward a Theory of Suppression by HERO Staff (Historical Evaluation and Research Organization, a subsidiary of T.N. Dupuy Associates)

Appendix G - Weapons Effectiveness and Suppressive Fire by George M. Gividen (ARI)

ARI TECHNICAL REPORT
TR-79-A19

A Further Look at the Prediction of Weapons Effectiveness in Suppressive Fire

by

Albert L. Kubala and William L. Warnick
HUMAN RESOURCES RESEARCH ORGANIZATION
300 North Washington Street
Alexandria, Virginia 22314

MAY 1979

Contract DAHC 19-75-C-0025

Monitored by
ARI Field Unit at Fort Hood, Texas

Prepared for

U.S. ARMY RESEARCH INSTITUTE
for the BEHAVIORAL and SOCIAL SCIENCES
5001 Eisenhower Avenue
Alexandria, Virginia 22333

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FOR THE BEHAVIORAL AND SOCIAL SCIENCES

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JOSEPH ZEIDNER Technical Director	**WILLIAM L. HAUSER** Colonel, US Army Commander

Research accomplished
under contract to the Department of the Army

Human Resources Research Organization

NOTICES

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

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9. PERFORMING ORGANIZATION NAME AND ADDRESS Human Resources Research Organization 300 North Washington Street Alexandria, Virginia 22314		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 2Q763743A775
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18. SUPPLEMENTARY NOTES

Monitored by Charles O. Nystrom, ARI Field Unit at Fort Hood, Texas

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Suppression
Small Arms Effectiveness

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This research and literature review investigated the relationship between acoustic signatures of small-arms projectiles and the suppressive behavior which results from soldiers' perceptions of danger. Kinetic energy, which is associated with perceived loudness of passing projectiles, appears to be the primary physical property of projectiles that affects behavior under fire. The report is written for military personnel.

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Army Project Number
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Human Performance
in Field Assessment
Contract DAHC 19-75-C-0025

Technical Report TR-79-A19

A FURTHER LOOK AT THE PREDICTION OF WEAPONS EFFECTIVENESS IN SUPPRESSIVE FIRE

Albert L. Kubala and William L. Warnick
Human Resources Research Organization

Submitted by:
George M. Gividen, Chief
ARI FIELD UNIT AT FORT HOOD, TEXAS

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Approved by:

Frank J. Harris, Acting Director
Organizations and Systems
Research Laboratory

Joseph Zeidner, Technical Director
U.S. Army Research Institute for
the Behavioral and Social Sciences

FOREWORD

The Fort Hood Field Unit of the Army Research Institute for the Behavioral and Social Sciences (ARI) provides support to Headquarters, TCATA (TRADOC Combined Arms Test Activity; formerly called MASSTER--Modern Army Selected Systems Test Evaluation and Review). This support is provided by assessing human performance aspects in field evaluations of man/weapons systems.

A war using modern weapons systems is likely to be both intense and short. US man/weapons systems must be effective enough, immediately, to offset greater numbers of an enemy. Cost-effective procurement of improved or new combat systems requires testing that includes evaluation of the systems in operational settings similar to those in which the systems are intended to be used, with troops representative of those who would be using the systems in combat. The doctrine, tactics, and training packages associated with the systems being evaluated must themselves also be tested and refined as necessary.

This report presents the results of an investigation originally designed to determine what aspects of the auditory signatures of passing projectiles are perceived as making the projectiles dangerous, resulting in suppressed behaviors. The report presents a review of the relevant literature, and examines kinetic energy as the primary physical property of projectiles that affect behavior.

ARI research in this area is conducted as an in-house effort, and as joint efforts with organizations possessing unique capabilities for human factors research. The research described in this report was done by personnel of the Human Resources Research Organization (HumRRO), under contract DAHC19-75-C-0025, monitored by personnel from the ARI Fort Hood Field Unit. This research is responsive to the special requirements of TCATA and the objectives of RDTE Project 2Q763743A775, "Human Performance in Field Assessment," FY 1978 Work Program.

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BRIEF

Requirement:

The work carried out in this study is that referred to in paragraph 2.2.23 of the Statement of Work dated 16 May 1977 under the title of "Suppression Research." The objectives of this effort were:

- To provide a review of the literature published since 1970 on fire suppression by small arms.
- To determine from information available what aspects of the acoustic signatures of projectiles contribute to their being perceived as dangerous and result in suppressed behaviors.

Procedure:

A field study conducted in the early 1970s produced a psychological rating of "perceived dangerousness" of a series of small arms fire events. A behaviorally anchored Suppression Index (SI) was also derived from a similar set of small arms fire events. It was concluded that the psychological scales were based almost solely on the subjects's reactions to the noises of the passing projectiles. However, no data on the acoustic signatures of the projectiles were obtained at that time. This effort was initiated as a literature review to determine whether data on acoustic signatures of the weapons employed were available, and if so, whether any aspect(s) of these signatures could be employed to "predict" the psychological scales. A review of the general literature on suppression was also conducted.

Principal Findings:

- Data on the acoustic signatures of projectiles down range from the weapon are extremely limited, and are not complete enough to be of any value in determining the relationship between signatures and the psychologically-derived Suppression Index and perceived dangerousness ratings.
- Kinetic energy, which is believed to be closely related to the perceived loudness of passing projectiles, appears to account for nearly 100% of the variance between weapons on both the Suppression Index and the perceived dangerousness ratings.
- Further research is needed to validate the findings relative to kinetic energy, and to better establish the mathematical relationship between miss distance, rate of fire, and psychological scales such as the Suppression Index.

Utilization of Findings:

Operations research analysts in attempting to play suppression in combat models have had to rely on intuition and fragmentary descriptions of behavior under fire to develop their models. As a result, the handling of suppression has been highly variable. The results of the analysis in this research should provide them with another tool to help refine computer models involving suppression play.

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Chapter 1

BACKGROUND

It has long been believed that most weapons, in addition to their casualty-producing capabilities, also have incapacitating psychological effects which may inaccurately reflect the actual threat. Earlier works dealing with these psychological effects[1,2,3,4,5] invoked the concept of fear. Essentially, all of these efforts were directed toward finding out which weapons were most feared by the respondents. Subjects queried included American, British, German, North Korean, and Communist Chinese soldiers. While these works did demonstrate that fear of a weapon and its casualty-producing capability were not perfectly correlated, only minimal information was obtained on the reasons for the observed discrepancies. Furthermore, as Terry[6] pointed out, the data obtained were strictly ordinal in nature with the scales typically ranging from most feared to least feared. In addition, the effects on the actual behavior of the individuals queried were not determined. In other words, it could not be determined whether these stated fears had any effect on the conduct or the outcome of a battle. Therefore, these earlier data are useful only as an aid in the formulation of hypotheses.

One of the behavioral results expected from fear of enemy weapons is the phenomenon called "suppression." The term suppression has long been a part of the Army's vocabulary. However, attempts to arrive at a precise definition have proven elusive.[7] Virtually all definitions of

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[1] J. Dollard. *Fear in Battle*, The Institute of Human Relations, Yale University, New Haven, Connecticut, 1943.

[2] H. Goldhamer, A. L. George, and E. W. Schnitzer. *Studies of Prisoner-of-War Opinions on Weapons Effectiveness (Korea)* (U), RM-733, Rand Corporation, Santa Monica, California, December 1951.

[3] L. A. Kahn. *A Preliminary Investigation of Chinese and North Korean Soldier Reactions to UN Weapons in the Korean War*, ORO-T-14 (FEC), Johns Hopkins University, 1952.

[4] L. A. Kahn. *A Study of Ineffective Soldier Performance Under Fire in Korea*, ORO-T-62 (AFFE), Johns Hopkins University, 1954.

[5] S. A. Stouffer, et al. *The American Soldier: Combat and Its Aftermath, Vol II*, Princeton, New Jersey: Princeton, University Press, 1949.

[6] R. A. Terry. *Toward a Psychological Index of Weapons Effectiveness. Part I: Field Studies*, Technical Report 1419-5, University of Oklahoma Research Institute, Norman, December 1964.

[7] L. A. Huggins, Jr. "A Simplified Model for the Suppressive Effects of Small Arms Fire," Masters Thesis, Naval Postgraduate School, Monterey, California, September 1971.

suppression attempt to relate the volume of fire of one force to a degradation of performance of the opposing force. For example, Winter and Clovis[8] define suppression as "...the causing of human reactions that reduce individual (unit) efficiency to fire, observe, and move." A Combat Developments Experimentation Command (CDEC) report[9] states that the TRADOC definition is "the degradation of specified combat activity for a particular period of time." According to Kinney,[10] "suppression is a short-term transient degradation in the combat performance of infantryman. It is produced by their behavioral response to the lethality potential (risk) of impacting weapons that do not incapacitate them." The Ad Hoc Group on Fire Suppression[11] states that suppression is:

> ...a process which causes temporary changes in performance capabilities of the suppressee from those expected when functioning in an environment which he knows to be passive. These changes are caused by signals from delivered fire or the threat of delivered fire, and they result from behaviors that are intended to lessen risk to the suppressee.

Numerous other definitions have been given in the literature, but all of those located were very similar to the preceding examples. All of the definitions imply that suppression is temporary, i.e., it is not a result of physical incapacitation due to injury or death. They also imply that some aspect of performance must be adversely affected before a force or an individual can be said to be suppressed. The performances most frequently mentioned are those of observation, returning fire, and maneuvering. However, a broader view was taken by the Ad Hoc Group.

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[8] R. P. Winter and E. R. Clovis. *Relationship of Supporting Weapon Systems Performance Characteristics to Suppression of Individuals and Small Units*, TR 73/002, Defense Sciences Laboratories, Mellonics Systems Development Division, Litton Systems, Inc., Sunnyvale, California, January 1973.

[9] Project Team II, US Army Combat Developments Experimentation Command, and Braddock, Dunn, and McDonald Scientific Support Laboratory, Fort Ord, California. *Dispersion Against Concealed Targets (DACTS), USACDEC Experiment FC 023*, Final Report, July 1975.

[10] D. G. Kinney. *Suppression Analysis Technique* (U), unclassified version of paper presented to 33 MORS, Weapons Planning Group, Naval Weapons Center, China Lake, California, undated.

[11] US Department of the Army, Office of the Deputy Chief of Staff For Research, Development, and Acquisition, Washington, D.C. *Report of the Army Scientific Advisory Panel Ad Hoc Group on Fire Suppression*, ODCSRDA Form 11, 7 July 1975.

For example, they spoke of the suppression of command and control activities through electronic warfare. Obviously, loss of communications is likely to degrade performance in other areas, especially maneuvering. However, most other writers appear to take a narrower view and consider the degraded performance to be a direct result of behaviors resulting from fear of incapacitation.

It should be noted that the contemporary definitions of suppression attempt to deal with observables, i.e., behaviors, while the earlier works relied on a purely mental concept of fear. It should also be noted that these behavioral definitions objectively permit anchoring the ends of any suppression scale. If no decrement in *performance* can be observed (regardless of what individual members of a force may state about the intensity of their fears), suppression is rated zero. If all observable behavior is devoted solely to the minimizing of personal risk, suppression is said to be complete or 100%. In other words, if the fire intensity is such that an individual devotes his total effort to seeking greater cover, he is totally suppressed. Increases in fire power beyond this intensity cannot therefore increase suppression. Despite these objectively defined end points, the measurement of the degree of suppression along the scale has proven to be difficult and controversial. For example, given a known level of fire, is it possible to relate the degree of suppression of a force with extremely limited mobility, but with the ability to observe the enemy and return fire, to that of a force with the ability to observe and maneuver, but with a limited capability of returning fire? Most likely, in either case the ability to observe the enemy will be the last function suppressed. However, the absolute or even the relative importance of each of these functions is difficult to establish. Furthermore, the degree of suppression is also dependent upon the mission. If he is adequately protected and concealed, a soldier observing enemy movement may be hardly suppressed by enemy machinegun fire. Under the same conditions, the soldier whose mission is to advance on the enemy might well be totally suppressed.

It can be plausibly argued that at any given time, suppression is either total or nonexistent. For example, assume that an infantryman is in a foxhole observing the enemy and firing as enemy personnel reveal themselves. Movement at this time is not a part of his mission. Further assume that machinegun fire suddenly begins to rake the area. The soldier will undoubtedly duck into his foxhole and abandon attempts to observe, return fire, or move. That is, he will be completely suppressed. However, shortly after the machinegun fire ceases, he will again observe and fire on the enemy. In this sequence of events, the soldier will go from being virtually unsuppressed, to being totally suppressed, to being virtually unsuppressed again. Although not explicitly stated as such, this line of thinking probably led the CDEC team[12] to view suppression as the percentage of time an individual was

[12] Project Team II, *op. cit.*

unable to perform a specific assigned duty during a given period of time. If one is willing to assume that suppression is always either near 0 or near 100%, the "percent time suppressed" is a very reasonable measure of the degree of suppression. As can be seen, attempts to define, much less measure, the degree of suppression have been fraught with problems.

In all of the literature located, the authors agreed that suppression was a "temporary" phenomenon. However, the meanings attached to temporary were quite variable. Huggins,[13] reported on a CDEC study in which a target was said to be suppressed if two projectiles passed within two meters of the target within an .04 minute time interval. The duration of suppression was .06 minutes, but could be extended for .01 minute for each projectile that passed within two meters of the target while it was suppressed. Translating this into seconds, the minimum suppression time appears to be 3.6 seconds, which is incremented by .6 seconds for each additional round. Kinney[14] states that "suppression is a short-term transient degradation...," and defines "short-term" as being "in the order of tens of seconds." The Ad Hoc Group[15] points out that most suppression models use constant durations with suppression time running from 10 to 60 seconds. They question the use of these short periods by noting that in the recent Mideast War, a non-killing hit on the turret would cause a tank crew to stop activity for as much as 8 to 10 minutes. Unfortunately, actual combat data relating type and intensity of fires, the range of individual behaviors, and the duration of suppression are practically nonexistent. Therefore, the current authors view these time estimates as merely "best guesses." Most attempts to determine the duration of suppression have been based on retrospective interviews of combat-experienced personnel. Variations in combat situations such as the types and intensity of fires, the amount and kind of protection, the relative size of the opposing forces, and the experience and personalities of the individuals make it extremely difficult to systematically compare the recollections of different individuals. Furthermore, the validity of retrospective data is always suspect, particularly when any behaviors reported could reflect adversely on the interviewee. Therefore, it is not surprising that the literature reports great variability in the estimated duration of suppression.

To further complicate the issue, investigators have stated that suppression can be either "reasoned" or "unreasoned."[16] Reasoned suppression is said to occur when an individual attempts to optimize the tradeoffs between his personal protection and the accomplishment of the mission. Unreasoned suppression is said to occur when the risk-reduction behavior is far out of proportion to the actual threat. Unfortunately, what seems reasoned to one may seem foolhardy to another, and

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[13] Huggins, *op. cit.*

[14] Kinney, *op. cit.*

[15] US Department of the Army, *op. cit.*

[16] Winter and Clovis, *op. cit.*

vice versa. As the Ad Hoc Group[17] pointed out, "reasoned performance" in a given situation must be defined. How does the individual weigh his personal survival against the importance of the mission? How does one realistically assess personal risk? Can the reasonableness of performance at any given time be evaluated in terms of percent casualties experienced? These and other similar questions must be answered before criteria for reasonableness can be determined. At first, it might seem that an individual who performed as if suppressed while not under fire was exhibiting "unreasoned performance." However, this is not necessarily the case. Suppression can be divided into two categories--reactive and threat.[18] Reactive suppression results from being taken under fire. Threat suppression occurs when there is a high *probability* of being taken under fire (especially if protection is poor). Kinney[19] refers to this latter kind of suppression as "anticipatory" suppression. He states that anticipatory suppression is based on a future risk, while reactive suppression is based on a current risk.

Naylor[20] implies that weapons designers need more information than is supplied by definitions of suppression alone. The weapons designer needs to know the particular characteristics of a weapons system which are associated with specific behavioral responses. The earlier data generally indicate the proportion of respondents who reported fear of each of a particular set of weapons. Data on why the weapons were feared tends to be sparse. Naylor presents data from an earlier study indicating that such things as accuracy of fire, lack of warning, rapidity of fire, noise, and a lack of defense were typically stated as reasons for fear of various weapons. Yet, inconsistencies existed. For example, noise was a frequently cited reason for fear of dive bombers. However, noise did not appear to be a major factor in a fear of artillery shelling. Naylor's thesis is that we know virtually nothing about the separate or combined contributions of weapons characteristics in terms of their effects on human behavior. In his point of view, the problem is:

> ...really one of assessing the effect of a particular stimulus, which is occuring under a particular set of circumstances or within a particular environment, upon the behavior of an individual or a group of individuals.

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[17] US Department of the Army, *op. cit.*

[18] *Ibid.*

[19] Kinney, *op. cit.*

[20] J. C. Naylor, et al. *Proceedings of the First Symposium on the Psychological Effects of Non-Nuclear Weapons, Volume I*, University of Oklahoma Research Institute, Norman, April 29, 1964.

Stated somewhat differently, we will be able to effectively assess the psychological effects of weapons, or, to predict the responses to new weapons systems only when we are able to quantify both the stimuli associated with weapons and the responses obtained from use of these weapons.

At this juncture, it might be well to examine why it is so important to predict the behavioral responses to the visual and auditory signatures of weapons. One reason, as Naylor pointed out, is that such information might be useful in designing future weapons systems. However, it is also critical that we know what responses should be expected to employment of existing weapons systems. Many decisions concerning the makeup and deployment of our armed forces are based on computer simulations of hypothetical future engagements. The results obtained are only as good as the input data and assumptions underlying the models used. Obviously, if suppression does in fact exist, then it should be played as part of the engagement. However, as was pointed out earlier in this discussion, attempts to model suppression heretofore have been based on "best guesses" of the modelers. The variability in how suppression is handled in the different models indicates an urgent need for better data. Inaccurate modeling of suppressive effects can only lead to less accurate decisions. Therefore, any data which improve the modeling efforts should be extremely useful. This research was initiated as an attempt to relate stimulus characteristics of *selected small arms* to psychologically scaled values of indexes of suppression and perceived dangerousness of each of these weapons. Hopefully, the results can be employed to improve combat models, and, as Naylor has suggested, provide useful information to weapons designers.

Chapter 2

RESEARCH PROBLEM AND LITERATURE REVIEW

Research Problem

Introduction. Kushnick and Duffy[1] reported on a series of studies aimed at relating the characteristics of small arms to their suppression capability. In an effort to generate hypotheses, they completed an extensive review of the literature and conducted interviews with a large number of combat veterans. They concluded that miss distance, caliber, and rate of fire were the primary determinants of suppressive capability. Based on their analyses of the literature and interview data, they designed a series of experiments to verify their hypotheses. In one of these studies, observers were placed in a pit and given a scenario describing a hypothetical battle situation in which they were to imagine they were involved. Small arms were then fired over the pit from a range of 150 meters. Varying lateral miss distances were employed. Miss distance was controlled by aiming the weapons at a series of targets emplacdd on the opposite side of the pit from the weapons. After each sequence, observers were asked to select one of seven alternative statements which would best describe their behavior under these circumstances on an actual battlefield. These alternatives are shown in Table 2-1.

These alternatives were later scaled in terms of the amount of suppression each represents through the use of Delphi techniques. These scaled values are shown in the second column of Table 2-1.

Following this, each respondent's reply to each situation was assigned the appropriate scale value, and the values were averaged across respondents and conditions to develop a suppression index for each weapon. The weapons and their scale Suppression Index (SI) values are shown in Table 2-2.

In another experimental study, data on perceived dangerousness of live fire events were obtained in the same physical environment described above. However, rather than a behavioral type scale such as was used in developing the Suppression Index, dangerousness was rated on a simple 7-point scale. The anchor points were "no personal danger" and "maximum dangerousness." It was concluded that the major factors producing a perception of dangerousness are the loudness of passing

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[1] S. A. Kushnick and J. O. Duffy. *The Identification of Objective Relationships Between Small Arms Fire Characteristics and Effectiveness of Suppressive Fire*, TR 72/002, Final Report, Mellonics Systems Development, Litton Industries, Sunnyvale, California, 3 April 1972. (For a less technical version, see G. M. Gividen, "Weapons Effectiveness and Suppressive Fire," in *Proceedings*, 13th Annual US Army Operations Research Symposium AORS XIII, 29 Oct. - 1 Nov., 1974, Fort Lee, Virginia, Vol II, pp 503-513.

Table 2-1. Response Alternatives to Fire Events

Response Alternative	Delphi Scale Value
A. Take cover as best I could, but wouldn't be able to observe or fire on the enemy at all.	100
B. Take cover as best I could and would be able to observe the enemy occasionally, but wouldn't be able to fire at the enemy at all.	90
C. Take cover as best I could and would be able to observe the enemy continuously but wouldn't be able to fire at the enemy at all.	80
D. Take cover as best I could, and would be able to observe the enemy occasionally and fire at the enemy occasionally.	59
E. Take cover as best I could, and would be able to observe the enemy continually and fire at the enemy occasionally.	34
F. Take cover as best I could, but would be able to observe the enemy continually and place continuous fire on the enemy.	17
G. Would continue doing what I had been doing before the incoming fire and wouldn't worry about getting better cover.	0

rounds, the proximity of passing rounds, and the volume of fires.[2] Since the proximity of passing rounds and the rates of fire were held constant, it was concluded that the loudness of the passing rounds was the primary determinant of differences in perceived dangerousness in the experiment. Loudness was believed to be closely related to the kinetic energy of the projectiles as they passed near the subjects. However, the relationship between kinetic energy and perceived dangerousness proved to be curvilinear. The tabled data, adapted from Kushnick and Duffy, are shown in Table 2-3. From this result, it can be concluded that either (a) kinetic energy is not linearly related to perceived loudness, or (b) other factors in the acoustic signature are at play in determining perceived dangerousness. It is interesting that the two weapons which caused the curvilinearity are those with the highest (XM645 flechette) and lowest (.45 caliber) velocities. It is conceivable that the frequency spectrum and duration of the sounds from these projectiles at the extremes of velocity may affect their perceived dangerousness above and beyond the loudness component. However, Kushnick and Duffy made no attempt to relate these characteristics to perceived dangerousness. In fact, no data on projectile signatures were obtained during the study. However, with interest in suppression still high, it was felt that it would be useful to determine whether or not other aspects of the auditory signatures of the projectiles could be employed to improve the prediction of perceived dangerousness. Therefore, this effort was initiated to (a) determine what information on the auditory signatures was available or could be made available, and (b) to determine whether these data could be employed to improve the prediction of the psychologically-derived measures by physical measures.

Approach. As originally conceived, this effort was to be conducted in two phases. The initial phase was to be an attempt to locate data on the auditory signatures of the small arms projectiles employed in the Kushnick and Duffy studies. However, it was also deemed advisable to accomplish an update review of the literature to determine if any relevant work had been accomplished since the very complete review reported by Kushnick and Duffy. A portion of the material reviewed was employed in the background discussion in Chapter 1. Additional discussion of the literature will follow in the next major section of this chapter.

The second phase of the effort was to be an attempt to relate the auditory signature data of the small arms projectiles to the psychologically-scaled values of suppression and perceived dangerousness. It was determined that only available data on auditory signatures should be used at this time. An attempt to obtain new data was viewed as too costly. The instrumentation required for obtaining accurate data on

[2] Another study was conducted to determine the suppressive effect of the visual signatures of impacting rounds. While these signatures were related to suppression, they did not play a part in the experiments in which the Suppression Index and the Perceived Dangerousness Index were derived.

Table 2-2. Suppression Scale Scores

Weapon	Mean SI	Standard Deviation
XM19	29.82	23.41
M16	35.10	22.83
AK47	36.44	24.84
M60	43.27	23.72
Caliber .50 MG	60.99	30.77

Table 2-3. Relationship Between Kinetic Energy (KE) and Perceived Dangerousness

Projectile	KE x 10^{-8}	Perceived Dangerousness Index
Caliber .50	27.79	47
M60	3.63	41
AK47	2.20	39
M16	1.33	37
Caliber .45	.93	27
XM645	.94	23

auditory signatures is highly sophisticated (e.g., see Garinther and Moreland[3]), and simply not available. In addition, duplicating the conditions under which Kushnick and Duff's subjects perceived the passing rounds would also be difficult. Therefore, it was felt that the available data should first be analyzed. If these data showed significant promise for predicting the psychological scales, then a determination would be made as to the desirability of obtaining new and more complete data on the auditory signatures.

Unfortunately, all of the data desired could not be located. Nevertheless, some further analysis of Kushnick and Duffy's data seemed warranted. The results of this analysis are presented in Chapter 3.

Discussion of the Literature

The primary source of the literature obtained was the Defense Documentation Center (DDC). However, personnel at the Human Engineering Laboratories (HEL), Test and Evaluation Command (TECOM), Picatinny Arsenal, the Army Environmental Hygiene Agency (AEHA), and the Ballistic Research Laboratories (BRL) were also contacted in an effort to insure completeness. The emphasis in the searches was on the more recent literature; that is, literature published since the review by Kushnick and Duffy. However, because of their perceived high relevance, a number of documents referred to by Kushnick and Duffy were also obtained. An attempt was also made to limit the documents obtained to those which dealt with the suppression of infantry units, and/or suppression resulting from the use of small arms. A considerable portion of the effort was also invested in the search for auditory signature data of small arms. The search in DDC was complicated by the inconsistency in the use of key words. For example, there were over 40 entries for the M16 rifle and associated equipment. While it was possible through proper coding of entries to form some groups for the searches, the process was still quite tedious. For example, by use of proper input codes, it was possible to retrieve information on all documents having key words such as M-16, M-16 rifle, M-16 rifles, M-16 gun, and M-16 guns. However, separate searches had to be made for documents with key words such as M 16 and M16. Also, in order to retrieve documents related to suppression, a variety of key words such as suppression, fire suppression, and weapons systems effectiveness had to be employed. All in all, approximately 100 combinations of key words were employed in the DDC searches.

The general literature on suppression can be divided into three broad categories. The older documents were primarily reports of interview and/or questionnaire studies. The newer documents dealt primarily

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[3] G. R. Garinther and J. B. Moreland. *Transducer Techniques for Measuring the Effect of Small-Arms Noise on Hearing*, Technical Memorandum 11-65, US Army Human Engineering Laboratory, Aberdeen Proving Ground, Maryland, July 1965.

with field experiments or the development of models for use in gaming. However, few of the reports reviewed were "pure" in that they fell exclusively into one of the three categories. Also, many of the reports contained substantial theoretical or general discussions of the nature of the phenomenon of suppression. Nevertheless, for convenience of discussion, the literature reviewed will be divided into the three categories suggested above.

Interview and questionnaire studies. Some of the general findings of the interview and questionnaire studies have already been presented in Chapter 1, and will not be repeated here. The reader interested in a more detailed unclassified review and discussion of these studies is referred to Naylor, et al.,[4] or Casey and Larimore.[5] However, there are a number of conjectures concerning interview and questionnaire studies that are of sufficient interest for at least a brief mention. For example, Palmer, et al.[6] point out that data obtained from POWs need to be scrutinized very carefully before validity can be assumed, as POWs may deliberately attempt to mislead the interviewer. Palmer, et al. also point out that many such studies employed structured interviews which may have tended to lead the interviewees. Questionnaires also tend to be structured in nature. Palmer, et al. recommend the use of an unstructured interview as the most valid approach.

There is evidence from the interview and questionnaire data that familiarity with a weapon tends to reduce fear of that weapon. Or, in the case of the especially effective weapons, fear may actually increase. In other words, familiarity with weapons tends to make fears more realistic. That is, the relative fear of various weapons is likely to become more in keeping with the actual casualty-producing ability or lethality of the weapon, as familiarity with the weapon increases. However, this was not always found to be the case. In some cases, greater fear was expressed for those weapons which had most frequently been used against the individual being questioned. Fear was also found to be associated with the reputation of a weapon. For example, US forces in Africa during WWII expressed great fear of the German "88" because of its reputation for extreme accuracy.

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[4] J. C. Naylor, et al. *Proceedings of the First Symposium on the Psychological Effects of Non-Nuclear Weapons - Volume I*, University of Oklahoma Research Institute, Norman, April 29, 1964.

[5] I. J. Casey and W. E. Larimore. *Paraphysical Variables in Weapon System Analysis*, AR 66-1, Analytic Services, Inc., Falls Church, Virginia, April 1966.

[6] J. D. Palmer, et al. *Investigation of Psychological Effects of Non-Nuclear Weapons for Limited War. Volume No. II, Experimental Studies*, ATL-TR-65-39, Vol II, Directorate of Armament Development, Weapons Division (ATWR), Eglin AFB, Florida, January 1966.

Although the evidence is not substantial, there are some indications that fear of weapons is at least in part culturally determined. These data have been reviewed by Casey and Larimore.[7] They present data from Kahn[8] comparing the fears of Chinese Communist forces and North Koreans to United Nations weapons. A portion of these data is shown as Table 2-4. However, Kahn suggests that other than cultural differences may account for the differences observed in the table. He suggests, for example, that different types of weapons may have been used against the two forces, or that different proportions of combat-experienced soldiers may have served in the two armies represented. Casey and Larimore also present data on fear responses to a first air raid. It was found that Russians were less frightened than either French or Italians. Further, the Russians tended to fear large bombs the most out of five possibilities, while the French placed large bombs third. Both groups, along with Italians, placed incendiary bombs last.

Table 2-4. Most Feared United Nations Weapons

	Percent	
Weapon	**Chinese**	**North Korean**
Airplane	52	23
Strafing	16	27
Bombing	7	19
Napalm	3	13
Artillery	50	38
Machineguns	5	3
Tanks	4	1
Tank Guns	4	2
Rifles	5	1
No. of Prisoners	238	305

The inconsistency of reports concerning the effect of noise has already been mentioned in Chapter 1. That is, noise was very frequently mentioned as a reason for fear of dive bombers, while it was virtually never mentioned in connection with fear of artillery. Page, et al.,[9]

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[7] Casey and Larimore, *op. cit.*

[8] L. A. Kahn. *A Preliminary Investigation of Chinese and North Korean Soldier Reactions to UN Weapons in the Korean War*, ORO-T-14 (FEC), Johns Hopkins University, 1952.

[9] M. M. Page, et al. "Prior Art in the Psychological Effects of Weapons Systems," in J. C. Naylor, et al., *Proceedings of the First Symposium on the Psychological Effects of Non-Nuclear Weapons - Volume I*, University of Oklahoma Research Institute, Norman, April 29, 1964.

point out that the British had little fear of "shrieking" bombs. This was because of the time they could be heard before they hit. Thus, they had ample warning and could take cover, rendering the bombs largely ineffective from the antipersonnel standpoint. This is in direct contrast to the data on fear of the shrieking dive bomber cited earlier. However, the troops reporting fear of the dive bomber were in the open and therefore had little affordable protection. Hence, it can be seen that situational factors are extremely important in determining what characteristics of a weapon will produce fear.

Experimental studies. Only two series of experimental studies were located in the literature search. One of these was the series of five studies reported by Kushnick and Duffy.[10] The general procedures employed in most of this series has already been described in the Research Problem section. The first experiment was a "policy capturing" experiment designed to determine what personal as well as weapon and scenario characteristics contributed to suppression ratings. It was during this experiment that the Suppression Index was derived. The second experiment was a miss distance estimation experiment, and the third dealt with the perceived dangerousness of various live fire events. The fourth study was designed to assess the suppressive effects of impact signatures, and the fifth to determine whether physiological responses were correlated with the psychological responses to live fire events. Data collection for the impact signature study differed somewhat from the other experiments. Rounds were actually fired into the ground approximately 15 meters in front of the pit, and subjects observed the impacts through periscopes. The general conclusions drawn from this series of studies were: (1) the major factors producing suppression are the loudness of passing rounds, the proximity and number of passing rounds, and the signatures associated with rounds impacting. (2) Within the limits of the study, suppression was shown to (a) decrease in a linear fashion with increasing miss distance, (b) to increase linearly with increases in rate of fire or volume of fire, and (c) to increase in a linear fashion with increases in the perceived loudness of passing projectiles. This series of studies by Kushnick and Duffy will also be referred to hereafter as the Litton studies.

The US Army Combat Developments Experimentation Command (USACDEC) conducted a series of suppression experiments employing a wide variety of both direct and indirect fire weapons. Data from two of the more relevant experiments have been summarized in a 1976 publication.[11] The intent of these studies was to determine the proximity of fire required

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[10] Kushnick and Duffy, *op. cit.*

[11] Deputy Chief of Staff for Combat Developments, US Army Combat Developments Experimentation Command, Fort Ord, California. *USACDEC Suppression Experimentation Data Analysis Report*, April 1976.

to suppress at the .5 and .9 probability levels, and to determine the volume of fires required to obtain the same suppression levels. The suppressees were ATGM gunners who simulated the engagement of a maneuvering armored element with an antitank missile. However, the suppressees did not have the capability of engaging the base of suppressive fires. The ATGM gunners used periscopes to detect, acquire, and track the armored vehicles. In order to motivate the ATGM gunners, rewards were given based on points obtained. The defenders were given maximum points for fully exposing their periscopes in firing at the enemy. Fewer points were awarded for partially exposing the periscopes and observing without firing, and no points were awarded for keeping the periscope down in the foxhole unable to fire or to observe. Negative points were given if the periscope was hit by the suppressive fire. It was assumed that each ATGM gunner would have to remain exposed for 15 seconds to complete the engagement. That is, if a gunner withdrew his periscope during the course of the engagement, it was assumed that the missile was "lost" and that the engagement would have to be re-initiated. Suppressive fire was placed at predetermined points in a predetermined pattern and rate by a team of "attackers." The likelihood that an ATGM gunner would be suppressed at each of several miss distances was determined empirically for each weapon involved. Weapons employed in the CDEC studies which were also employed in the Litton study were the .50 caliber machinegun, the M60 machinegun, and the M16A1 rifle. It was discovered that the probability of suppression is influenced by proximity of fire in a relatively orderly or predictable manner. It was possible to model radial miss distance in meters by the following equation:

$$RMD = Ae^{B\ P(S)}$$

Where: RMD is the miss distance in meters

P(S) is the probability of suppression

A and B are constants associated with each specific weapon type.

For the M60 machinegun, A = 89.556 and B = 5.395. Figure 2-1 presents a curve drawn through points computed for miss distances of .5, 1, 3, 6, 10, 15, and 20 meters. As can be seen, a miss distances of 6 meters results in a .5 probability of suppression, while a miss distance of less than 1 meter is required for a .9 probability of suppression. It should be noted that the data entering into each of the models was based on the results of all of the studies in which a particular weapon was involved, if the data were considered valid.

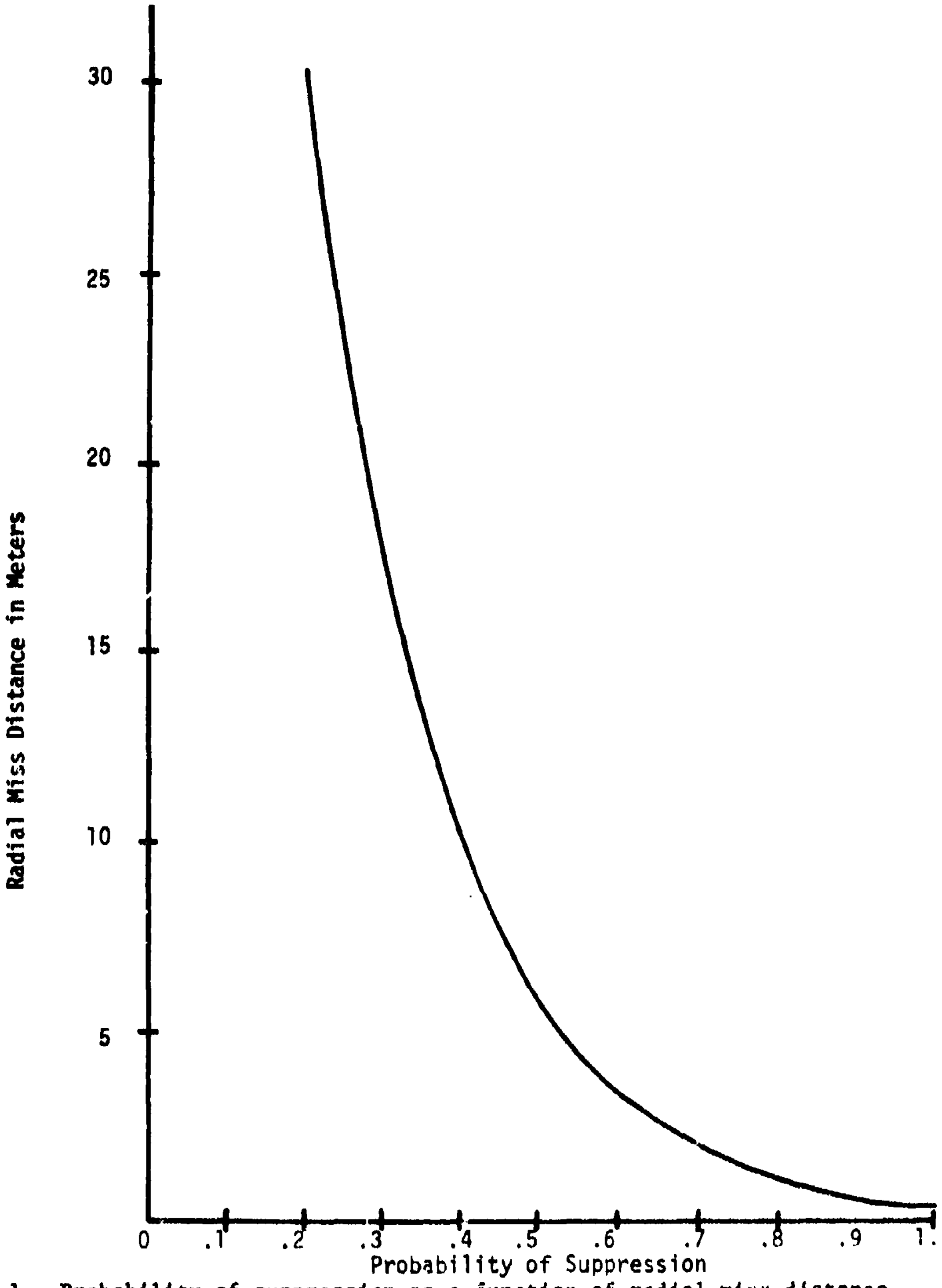

Figure 2-1. Probability of suppression as a function of radial miss distance.

Another CDEC study[12] investigated the effect of concealment on suppression. As might be expected, targets in concealed positions were less suppressed than those in visible positions. However, an interesting but unexpected result was obtained. There was a consistent tendency for the M16A1 in the semi-automatic mode to be more suppressive than in the automatic mode. In other words, rounds fired singly over a 30-second period tended to be more suppressive than rounds fired in 3-round bursts when the same total number of rounds were fired per unit of time. The authors speculate on this finding thusly:

> Since automatic fire is often believed to be more suppressive, the M16A1 on semi-automatic should have been the least suppressive of the dispersions used. The results indicate that this may not be true; in fact, the semi-automatic condition tended to be one of the most suppressive dispersions. Since 18 rounds per event were fired in each of the seven dispersions, there were six opportunities to suppress targets in the three-round burst mode, and 18 such opportunities in the semi-automatic mode during each 30 second trial. Therefore, the greater volume of fire associated with each trigger pull on the three-round burst may not compensate for the increased number of trigger pulls available with the same number of rounds in the semi-automatic mode. When the targets were visible, each trigger pull often was in direct response to sighting a target; therefore, the targets could be suppressed more times during a trial by the semi-automatic mode. The fact that the semi-automatic mode received a more suppressive ranking for visible than concealed targets supports this conjecture.

It seems to the present authors that an attempt should be made to replicate the finding just described. If the finding can be replicated, it should prove useful to both commanders and to weapons designers. The ability to fire rounds singly saves both ammunition and wear and tear on weapons, and may be equally or more effective in suppressing a hostile force.

One major difference between the CDEC studies and the Litton studies was that CDEC relied largely on objective data, while Litton

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[12] Project Team II, US Army Combat Developments Experimentation Command, and Braddock, Dunn, and McDonald Scientific Support Laboratory, Fort Ord, California. *Dispersion Against Concealed Targets (DACTS), USACDEC Experiment FC 023*, Final Report, July 1975.

relied on subjective data.[13] However, only one notable discrepancy in the conclusions drawn has been detected. Data from the CDEC study were suggestive of a logarithmic relationship between miss distance and level of suppression (see Figure 2-1). The Litton study concluded that "within the limits of the study," suppression was found to decrease in a *linear* fashion with increasing miss distance. However, the explanation for this apparent difference may be found in differences in the experimental procedures employed. In the CDEC studies described, the rounds may have actually passed closer to the observers than in the Litton study. Also, though it is not stated in the reports, the observers may have seen muzzle flashes and observed round impacts as they were employing periscopes above ground level. In the Litton studies where the Suppression Index and Perceived Dangerousness Index were derived, the observers were below ground and had no opportunity to observe muzzle flashes or impacts. Furthermore, the targets at which the weapons were fired were above ground level. From the description presented in the Litton report, the present authors estimate that the nearest miss distance was approximately 3.5 meters. Note that in Figure 2-1, that most of the curvilinearity occurs below 3.5 meters. That is, the curve is relatively straight at ranges from 3.5 meters up. If only these data were available, it would be easy to conclude that the relationship was linear. The CDEC reports present no data relative to the Litton conclusion that suppression increases with the perceived loudness of passing projectiles. Both sets of studies conclude that the proximity and number of passing rounds are associated with suppressive behavior.

Models

General considerations.

The belief that suppression does, in fact, exist, and does affect the outcome of battles, has provided the impetus for the development of mathematical models of suppression for inclusion in computer battle simulations. To the extent that the models realistically portray suppression effects, the computer simulations are improved. However, the authors of virtually all the documents describing model development admit that the models are based on assumptions and require validation. Furthermore, the assumptions vary from model to model. For example, in the FAST-VAL model,[14] it is assumed that an attacking battalion will break when they have 20% casualties and an attacking company will break when they have 30% casualties. It is further assumed that a defending

[13] CDEC also collected subjective data during the DACTS study but found it more variable than the objective data, and therefore, placed greater reliance on the objective data.

[14] S. G. Spring and S. H. Miller. *FAST-VAL: Relationships Among Casualties, Suppression, and the Performance of Company-Size Units*, RM-6268-PR, Rand Corporation, Santa Monica, California, March 1970.

battalion will break when they reach 40% casualties and a defending company will break when they reach 50% casualties. Johnson[15] points out that the theater battle model assumes that an attacker breaks contact when he suffers 15% casualties, while a defender breaks contact after suffering 30% casualties. Obviously, both sets of these assumptions cannot be correct. Also, the use of a fixed percentage does not seem to be realistic. An Operations Research Office report[16] describes the analysis of a number of battles in which US forces were both in attack and defensive postures. The breakpoints proved to be quite variable from battle to battle. All of the conditions leading to this variation could not be ascertained. However, such factors as the total length of the battle and the availability of reinforcements appear to be factors. The authors also suggest that the quality of leadership and experience of the personnel *may* have been factors. The influence of factors such as these must be determined before the models can be refined.

As discussed in Chapter 1, there is also disagreement on the duration of suppression. The Ad Hoc Group[17] noted that most models assume constant durations of 10 to 60 seconds. Again, the employment of a constant value seems unrealistic. Concealment, for example, was shown by CDEC[18] to be related to suppression time, with concealed targets being less suppressed than targets in the open. Other factors are undoubtedly involved. However, refinement of this aspect of the models must wait the accumulation of data delineating the contribution of the various factors. Further experimental research, and possibly further analysis of past battles, are required.

Work conducted by the Systems Research Center at the University of Oklahoma suggests the difficulties that are likely to be encountered in attempts to refine battle simulations to fully account for psychological

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[15] E. C. Johnson, Jr. "The Effect of Suppression on the Casualty Exchange Ratio," Masters Thesis, Naval Postgraduate School, Monterey, California, March 1973.

[16] D. K. Clark. *Casualties as a Measure of the Loss of Combat Effectiveness of an Infantry Battalion,* TM-ORO-T-289, Operations Research Office, Johns Hopkins University, August 1954.

[17] US Department of the Army, Office of the Deputy Chief of Staff for Research, Development, and Acquisition, Washington, D.C. *Report of the Army Scientific Advisory Panel Ad Hoc Group on Fire Suppression,* ODCSRDA Form 11, 7 July 1975.

[18] Project Team II, *op. cit.*

variables. For example, Terry, et al.,[19] formulated a psychological index of weapons effectiveness. They described the psychological index as "a system of measurements, which will permit quantitative description of the psychological effects of weapons." The index is referred to as the SRC Psychological Index, where S stands for signature value, R for reputation value, and C for context value. The signature variables are sound spectrum, sound intensity, light spectrum, light intensity, injury capability, and flame capability. Despite the multiplicity of factors considered, Terry, et al., did not mention impact signatures, which the Litton studies showed did affect psychological ratings. The reputation variables are familiarity, experience, predictability, forewarning, accuracy, lethality, countermeasures, and protection. Under context are listed 16 force variables, 10 unity variables, and 4 leadership variables. Force refers to those factors relevant to the degree of military might which can be employed by an enemy. Unity variables are those which are relevant to the cohesiveness of an enemy unit, and include such things as propaganda effects, the reputation of the unit, and their personal motives. The leadership variables pertain to leadership quality. As can be seen, assuming that all of the variables listed by Terry and co-workers are relevant to the psychological effects of a weapon, prediction of the effects is exceedingly complex. Terry, et al., were not dealing specifically with suppression, but with psychological effects in general. However, it is certainly conceivable that all of the variables mentioned might be factors in the suppressive capability of a weapons system.

Page, et al.,[20] delve into the responses to weapons systems. They state that weapons-specific variables (e.g., weapon efficiency, visual aspects, noise, duration, etc.) and situational variables (available protection, proximity, leadership, mobility, etc.) form the stimulus complex which impinges on the individual human. These variables interact with personal characteristics, which they refer to as organismic variables. Organismic variables are defined as experience, expectations, personal involvement, physiological condition, and predisposition. The result is a set of responses. These responses are divided by Page, et al., into immediate behavioral changes and long-range behavioral changes. Immediate changes include such things as panic, immobility, fatigue, poor performance, and flight or escape behavior. Long-range changes might be lowered morale, irrational thinking, regression, or even neurotic and psychotic disorders. This concept by Page, et al., of course, assumes a behavioral response which is desirable from the standpoint of the weapon user. Otherwise, the weapon would have no relevant psychological effect.

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[19] R. A. Terry, et al. *Development of Weapons Design Criteria Based on the SRC Psychological Index: An Investigation of Signature, Reputation and Context Effects*, Technical Report AFATL-TR-87-185, Air Force Armament Laboratory, Air Force Systems Command, Eglin AFB, Florida, October 1967.

[20] Page, et al., *op. cit.*

The work of Page, et al., and Terry, et al., does illustrate the complexity of the problem of predicting the psychological effects of weapons. However, it should be noted that the problem posed for this present research is less complex. Kushnick and Duffy noted that their respondents were reacting primarily to the sounds of the passing projectiles. What Terry, et al. refer to as context variables probably played an insignificant role. The situation or scenario given to each respondent was only briefly described, and the responses were limited to the seven choices presented. Organismic variables undoubtedly did come into play. That is, each individual reacted in his own individual manner. No attempt, however, was made to measure these variables other than to obtain a very limited amount of biographical information. Therefore, our present concern is almost solely with the signature variables.

Huggins[21] presents an explanation of how the suppression pheonomenon works.. Once a fire fight is initiated, all combatants tend to take cover. The next reaction is to assume a firing position and attempt to locate targets on which to deliver aimed fire. If no targets can be detected, a normal reaction is to deliver area fire at the assumed target location. Thusly, the fire fight tends to restrict the movement of the individual combatants. If one side is able to increase its fire, the other side is forced to take greater cover, is less able to detect targets, and therefore, it less able to return fire. In this manner, one side tends to assume fire superiority and the other side is said to be suppressed. The more one side is suppressed, the less they can deliver fire, and therefore the degree of suppression increases as the opposing side is able to deliver even greater volumes of fire. In theory at least, one side could become totally suppressed, allowing the other side to maneuver freely against them. However, in practice, there is a limit to the amount of fire any one side can deliver. Weapon wear and ammunition supplies dictate some restraint. Also, unless some of the fires are lethal, the suppression will only result in a delay and not a victory. In other words, the purpose of suppression appears to be that of gaining the advantage in mobility and the ability to observe, but must be followed by lethal fire in order to achieve a victory. Tepas[22] also discusses the purpose of suppression. He feels that it is a harassment designed to fatigue the enemy by interference with work-rest cycle and biorhythms. Ideally, the harassment weapons should

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[21] A. L. Huggins, Jr. "A Simplified Model for the Suppressive Effects of Small Arms Fire," Masters Thesis, Naval Postgraduate School, Monterey, California, September 1971.

[22] D. I. Tepas. "Some Relationships Between Behavioral and Physiological Measures During a 48-Hour Period of Harassment; A Laboratory Approach to Psychological Warfare Hardware Development Problems," in J. C. Naylor, et al., *Proceedings of the First Symposium on the Psychological Effects of Non-Nuclear Weapons - Volume I*, University of Oklahoma Research Institute, Norman, April 29, 1964.

fatigue the enemy to the extent that he eventually falls into a deep sleep, and is therefore completely suppressed. That this may actually happen is attested to by an incident reported by Page, et al.[23] They state:

> An example of hyperreaction is given in a report from a company pinned down while on the offensive in Korea. While undergoing intense fire and in-fighting for several hours, officers reported at mid-day that their most difficult problem was keeping the men awake and firing their weapons. This feeling of fatigue and extreme sleepiness, where it was not physically justified, was an avoidance hyperreaction to an especially intense weapons effect.

Tiedemann and Young[24] present an interesting notion on suppression which is essentially weapons-independent. They suggest that successive impacts of rounds coming closer and closer to an individual are likely to be more suppressive than rounds going in the other direction, or rounds randomly placed, or all hitting in the same spot. Whether this is true or not, it has a logical appeal. It might even be assumed that impacts at successively greater distances from an individual would hardly have any suppression effects at all.

Burt, et al.,[25] report on an interesting finding which certainly seems to be related to suppression. In an analysis of several battles, it was found that as artillery strength increased, the relative proportion of casualties by artillery decreased. The same apparently contradictory relationship was also found for small arms. This may be explained in part by assuming that increases in one kind of fire power caused personnel to take cover from that kind of fire power. However, it is difficult to imagine that personnel taking cover from artillery fire would not also be protected from small arms fire. Nevertheless, Burt, et al., suggest this possibility. They state:

> It seems reasonable to expect that when the enemy artillery fire power is great, stronger friendly bunkers are constructed and unnecessary friendly movement is curtailed. In addition, increased

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[23] Page, et al.,

[24] A. F. Tiedemann, Jr. and R. B. Young. *Index of Proximity: A Technique for Scoring Suppressive Fire*, ER 6419, AAI Corporation, Baltimore Maryland, October 1970.

[25] J. A. Burt, et al. *Distribution of Combat Casualties by Causative Agents*, Technical Memorandum RAC-T-445, Research Analysis Corporation, McLean, Virginia, March 1965.

> enemy artillery fire power may have been employed to allow the enemy infantry to come into direct contact with the friendly forces where they would make use of their small-arms weapons. This would reduce the percentage of casualties caused by artillery but increase the percentage caused by enemy small arms.

The authors also point out that their data are based on the *relative* or proportionate number of casualties. That is, increases in artillery fire power may also cause increases in the absolute number of casualties, but may still comprise a relatively smaller proportion of the total casualties.

In closing this general discussion section, reference is made to the work Winter and Clovis,[26] who followed up on the earlier work by Kushnick and Duffy. These authors were unable to find any quantitative data on suppressive effects. Due to this lack, they analyzed over 100 anecdotal reports of combat situations from WWII, Korea, and Vietnam. The level of suppression was determined judgmentally by comparing the behaviors described in the various reports. Unfortunately, quantitative data on a number of crucial variables such as volumes of fire were not available. Therefore, considerable subjectivity was involved in the analysis. They searched specifically for data on signatures, including visual, auditory, olfactory, seismic, and thermal signatures. They divided signatures into platform signatures, initiation signatures, trajectory signatures, and terminal signatures. Suppressive effects were noted on the ability to fire, move, observe, and communicate. The authors concluded that the "expected fraction of casualties," or lethality expectations associated with the weapon, takes into account all of the multiplicity of characteristics considered by others. Therefore, the model they developed had one parameter for weapons performance and one for "subjective aspects associated with human beings. This conclusion, that lethality is the only weapon parameter involved in suppression, certainly has appeal. If true, weapon signatures as such play no part in suppression except as recognition aids. That is, if the signature identifies the weapon as being of high lethality, it will lead to greater suppressive behavior. However, the present authors feel that this approach is too simplistic, as lethality is only one of a number of relevant factors. Other studies have consistently shown that fear of a weapon and its casualty-producing ability are not perfectly related, even among highly experienced battle veterans. But, until the contribution of other factors, if any, can be determined, the use of a single factor such as lethality may be the best approach. With regards to the human factors involved, these authors

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[26] R. P. Winter and E. R. Clovis. *Relationship of Supporting Weapon Systems Performance Characteristics to Suppression of Individuals and Small Units,* TR 73/002, Defense Sciences Laboratories, Mellonics Systems Development Division, Litton Systems, Inc., Sunnyvale, California, January 1973.

make an interesting recommendation. They recommend that no further experimentation on suppression be done. They feel that the suppression phenomenon is too complex and that the state-of-the-art in the behavioral sciences is not sufficiently advanced to yield any results of practical value.

Invariant models.

No attempt was made to locate information on all of the computer battle simulations devised by the military services. Many of the models originally examined did not play suppression at all, and will not be discussed here. There are undoubtedly others which do play suppression on which no information was located during the literature search. A complete reporting and description of the models reviewed did not seem necessary, as they had much in common. Therefore, the models which will be briefly discussed below should be considered as only a sampling of the total universe.

The models developed to date are largely invariant. That is, there is no "human factor" built into the assumptions. A given fire event in a given circumstance always results in the same degree and duration of suppression. This does not mean that the authors do not realize that a human factor exists. Most admit that it does, but that they lack the means for quantifying it. So, in essence, the models assume an "average" behavioral response on the part of the suppressed force. However, as discussed earlier, there is a notable lack of agreement on such things as the duration of suppression and the breakpoints (in terms of percent casualties) at which a force will abandon its mission.

A brief review of some of the major features or characteristics of some of these models is presented below.

a. Kushnick and Duffy used kinetic energy of the projectiles as a first approximation of the suppressive effects of a weapon. (See pages 2-1 through 2-3 of this chapter.) As mentioned earlier, they found that a curvilinear relationship existed between kinetic energy and perceived dangerousness. This particular finding will be discussed more fully in Chapter 3. The authors do acknowledge that factors such as the nature of the mission, availability of cover, combat experience, training, time in combat, and basic psychological makeup of the individual do mediate the suppressive effects of weapons. However, they make no attempt to deal with these variables in studying the relationship between kinetic energy and individual variations in perceived dangerousness. They present data dealing with only the average of the responses.

b. Aiken, et al.,[27] employing the data obtained by Kushnick and Duffy, attempted to scale weapons effects between 0 and 100% suppres-

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[27]A. C. Aiken, W. L. Phillips, and D. V. Strimling. "Individual Suppression as Induced by Direct Fire Solid Projectile Weapons: Its Effect and Duration," (U), ARI paper, 30 April 1975.

sion. To do this, they assumed that no fires would result in no suppression, and that a specific level and proximity of fires from a given weapon would result in 100% suppression. Employing the kinetic energy of projectiles, they were able to derive constants for their equations which relate all fires to this scale. However, they were quick to point out that once suppression reached 100%, that no additional fires could result in a greater degree of suppression. In other words, once the critical level of fires was achieved and suppression was complete, increasing fires would have no further suppressive effect and would therefore be wasteful.

c. Kinney,[28] though concerned with the development of a model for predicting suppression effects from fragmenting explosive warheads, assumes that miss distance is the only criterion for determining suppressive behavior. However, since various miss distances for various weapons represent different kill probabilities, he assumes that P_k is actually the physical variable which induces the psychological response of suppression.

d. Like Kinney, Tiedemann and Young[29] assume that the proximity of impacting rounds is the determinant of suppressive behavior, and they develop an index based on impact distances. Moreover, they state that successively closer impacts result in greater suppression than impacts at successively greater distances. However, they make no attempt to deal with individual differences or the effects of specific signatures of weapons systems.

e. Burt, et al.[30] attempted to relate such things as enemy personnel strength, artillery fire power, small arms fire power, ammunition supply, and weather to the incidence of casualties caused by either artillery, small arms, bombs, etc. Other qualitative variables were considered, such as terrain, vegetation, and morale, but were discarded because data were simply not reliable or were incomplete. Ammunition supply was discarded because data were not available in many instances. Burt and his co-workers analyzed data for five WWII battles and 16 Korean battles. They obtained a multiple correlation of .85 for predicting casualties from artillery, and a correlation of .77 for predicting casualties from small arms. However, conflicting results were obtained in the validation attempt. The equations failed to predict casualties in another battle from WWII, but were quite good in predicting casualties from another battle in the Korean War. In developing the equations, small arms were considered as a single category and casualties produced by different kinds of small arms were all considered to be the same. While the correlations are quite substantial, they do fail to

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[28] Kinney, *op. cit.*

[29] Tiedemann and Young, *op. cit.*

[30] Burt, et al., *op. cit.*

account for a considerable portion of the variance. In other words, measures of weapons lethality alone are not necessarily good predictors of casualties. The observed differences in casualty rates between battles *may* have been due to differences in enemy firing accuracy (i.e., proximity of impacting rounds). It *may* also have been due to differences in the protection available for or experience levels of the friendly forces. Both of these latter factors would also be *expected* to be related to suppressive behavior. If these factors were also at play, measures of lethality (including proximity measures) alone would be expected to predict neither casualties nor the degree of suppression of friendly forces. Further data are needed to determine the contribution of the various factors.

The models described indicate something of the range and types of models which have been developed. There are many others. The Ad Hoc Group, for example, presents a table listing the major characteristics of six other models of varying sophistication, all of which appear to be of the invariant type.

Examples of human factors models.

The models which include a human factor also make many of the same kinds of assumptions as the invariant models. That is, the weapons effects portion of the models is typically calculated in the same manner as in the invariant models. However, the final results are modified by introducing a human factor.

a. The SRC Psychological Index developed at the University of Oklahoma[31] represents an attempt to model all of the non-weapons specific factors in weapons effects. Strictly speaking, the Index is not a model since a means for numerical computation of index values was not provided. Rather, it simply provides a framework for a model which is in need of validation. Since this psychological index was discussed at some length earlier, no further details will be presented here.

b. Winter and Clovis[32] developed a model based on the expected fraction of casualties and a human factors coefficient. The expected fraction of casualties was based on the number of rounds fired, the lethal area per round, the area over which target elements are dispersed, and the circular probable error. They state that the human factors coefficient (rho):

> ...represents the aggregate of effects of human factors and other intangibles relating to morale, leadership, tactical situation, fear/danger ratio, and so forth; it has a nominal

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[31]Terry, *op. cit.*

[32]Winter and Clovis, *op. cit.*

value of 1. Use of values greater than 1 implies conditions resulting in higher suppressive levels than the threat would typically elicit; inexperienced troops, for example. If conditions are such that lower than typical suppression levels will occur, as might be in the case of a crucial defense by veteran troops, then a value of rho less than 1 is appropriate.

Unfortunately, the value of the human factors coefficient must be determined subjectively.

c. FAST-VAL II (Forward Air-Strike Evaluation)[33] is a model developed by the Air Force "...to define in analytic terms those relationships that describe the performance of a well-led and well-disciplined infantry company during a fire fight." Weapons effects are modeled in FAST-VAL by computing casualties based on the numbers of personnel in a given area and the levels of fire directed against them. The vulnerability of personnel is determined by the posture of the personnel. For example, personnel may be assumed to be in the prone position, standing in foxholes, crouching in foxholes, or in log bunkers. When the casualty rate exceeds a given value, personnel revert to a less vulnerable posture. Less vulnerable postures represent suppressed states. When the casualty rate for a given period of time is less than some fixed number, personnel revert to a more vulnerable posture. The human factor is built into the model by the user in two ways. One, the user determines the casualty rate at which a force will seek their second, more suppressed posture. Two, the user selects a fractional efficiency for each of the postures available in the model. In this way the user determines both when suppression will occur and what its effect will be on the performance of the suppressed individuals. At least according to the description provided by Spring and Miller,[34] percent casualties is the only factor entering into suppression. This seems a bit unrealistic in terms of what other investigators have found about behavior under fire.

Although they made no attempt to model the human factor, other writers have indicated that human factors variables ought to be included in models. For example, Reddoch,[35] though presenting a model of the invariant type, suggests that human considerations may alter the relationship between lethality and suppressed behavior. He suggests that when a weapon becomes too lethal, it may have no suppressive effect at all. Reddoch invokes the concept of "negative suppression" for this

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[33] Spring and Miller, *op. cit.*

[34] *Ibid.*

[35] R. Reddoch. "Lanchester Combat Models With Suppressive Fire and/or Unit Disintegration," Masters Thesis, Naval Postgraduate School, Monterey, California, March 1973.

contingency. If a weapon is so lethal that the target individuals believe that seeking protection will be useless, then they will make an all-out effort to destroy the weapon before it hits them. He cites flamethrower tanks as such weapons during WWII. Normally, personnel in bunkers would be suppressed by fire from conventional tank weapons. However, the flamethrowers represented a threat of near-certain destruction regardless of the bunker, so that virtually any risk appeared justified to destroy the tanks. The same situation held when gun boats in Vietnam had their 40mm weapons replaced by the 105mm howitzer. The 40mm's were replaced because they had proven ineffective against enemy bunkers. The 105mm was able to penetrate and destroy the bunkers. The result of the change was increased friendly casualties. Again, the enemy felt that since the bunkers offered virtually no protection, they were not suppressed, continued to fire, and inflicted heavier casualties on friendly forces.

Casey and Larimore[36] concluded that both the culture in which personnel were raised and their individual personalities affected their reactions to various kinds of weapons. They suggested the concept of a "modal personality" to account for these kinds of differences. Casey and Larimore also feel that the situation is an important determinant of behavior under fire. The situation is made up of the physical objects and conditions (cover, mobility, etc.). However, the authors suggest that it is more the combatant's perception of the situation than the actual situation which influences his behavior.

To recapitulate, virtually all of the model makers, even those who developed invariant models, believe that a human factor exists. However, attempts to include human variation in models have been rudimentary at best. It is obvious that a great deal more work needs to be done to define the situational, cultural, and individual variables which influence behavior under fire.

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[36] Casey and Larimore, *op. cit.*

Chapter 3

ANALYSIS

The original intent of this effort was to determine whether any aspect of the acoustic signatures of the weapons employed by Kushnick and Duffy[1] could aid in predicting the Suppression Index and Perceived Dangerousness Index they derived. Based on their own observations, plus reports from their subjects, they felt that the acoustic signatures of the passing projectiles were virtually the sole determinants of the ratings made. They stated:

> It was the opinion of both the subjects and the DSL analysts that the basic stimulus that allowed the subjects to perceive and note the dangerousness of the events in the field experiment was produced by the projectile signatures and not by the characteristics of the muzzle blasts of the weapons themselves.... The obvious overt characteristic producing the perception of danger is the loudness of the signature of passing projectiles....

The purpose of the present exercise was to obtain some notion on what aspect or aspects of the signatures affected suppression other than perceived loudness. Such information, if later proven valid, might be of considerable use to both commanders in the field and to weapons designers. It was, of course, realized that any results would be tentative, due to the small number of weapons involved in the study. However, the results were not intended to provide the ultimate solution. Rather, they were only intended to suggest hypotheses to provide direction to further experimental work on suppression.

Unfortunately, the data desired could not be located. Much of the relevant data located were not in the open literature, but rather were obtained from the files of various agencies through personal contacts with individuals in those agencies. All of the individuals contacted expressed serious doubts that the type of data requested existed at all. Two reasons were given. First, the measurement of weapons signatures was made almost entirely in the interests of safety. The efforts were directed towards determining whether weapon noises met design specifications and/or exceeded the standards set forth in MIL-STD 1474 (MI).[2]

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[1] S. A. Kushnick and J. O. Duffy. *The Identification of Objective Relationships Between Small Arms Fire Characteristics and Effectiveness of Suppressive Fire,* TR 72/002, Final Report, Mellonics Systems Development, Litton Industries, Sunnyvale, California, 3 April 1972.

[2] Department of Defense. "Noise Limits for Army Materiel," MIL STD-1474 (MI), Washington, D.C., March 1973.

Therefore, measurements were typically taken at the firer's ear, and at distances up to two meters to the left and right of the muzzle. These latter measurements were to determine whether or not the weapon posed a hearing hazard to adjacent individuals. In the case of weapons fired from a vehicle, measurements were taken at the various crew positions. It was pointed out, that at least with small arms, there was little concern about the safety of individuals 150 meters down range, as friendly troops were unlikely to be in such positions. Only two studies were located where down range measurements were obtained. Second, the instrumentation required to accurately measure weapons signatures is extremely sophisticated and is believed to be available only to research and development agencies. Therefore, personal contacts felt that if any such data were available, it would have been obtained by or known to personnel at the various agencies contacted. Since none of the personal contacts recalled having seen any such data, they felt that it was unlikely to have ever been obtained.

The data which were obtained dealt largely with peak sound pressure levels and with the durations of the A and B waves. Some analyses of the sound spectra were available, but were judged to be of little use. First of all, most of the measurements were made near the weapon and contained blast as well as projectile noises. Secondly, there appeared to be no clear-cut differences in the spectra that were easily quantifiable. For example, Garinther and Kryter[3] provide data showing that the M16 spectrum has a relatively flat amplitude between 0 and 15,000 hertz, except for short bandwidth dips around 7000 and 9000 hertz. The spectral analysis of the M14 is similar, except that the big dip in amplitude centers at about 12,000 hertz with a smaller one at 3000 hertz. Several other weapons showed no such missing bands in the lower part of the audible spectrum. With the small number of weapons for which suppression indices were available, attempts to use these types of data did not appear warranted.

Although most of the measurements of acoustic signatures were obtained near the weapon to evaluate hearing hazards, some data were obtained down range. These data were not obtained to evaluate the suppressive qualities of the weapons. Rather, they were obtained to determine the ranges at which passing projectiles could be detected and to ascertain whether the actual location of the weapon itself could be determined. These data, reported by Garinther and Moreland,[4] indicate

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[3] G. R. Garinther and K. D. Kryter. *Auditory and Acoustical Evaluation of Several Shoulder Rifles*, Technical Memorandum 1-65, US Army Human Engineering Laboratories, Aberdeen Proving Ground, Maryland, January 1965.

[4] G. R. Garinther and J. B. Moreland. *Acoustical Considerations for a Silent Weapon System: A Feasibility Study*, US Army Human Engineering Laboratories, Aberdeen Proving Ground, Maryland, October 1966.

the complexity of the problem addressed by this effort by enumerating the wide variety of factors which affect down range acoustic signatures of projectiles.

Meteorological conditions, especially humidity and wind (both direction and velocity), were found to have significant effects on audibility. Similarly, the density of vegetation was found to influence the signature. The mental state of the listener was also found to be important. For example, subjects whose sole task was to await and attend to projectile noises detected at greater ranges than subjects who were also attending to another task. However, division of attention should not have been a factor in the Kushnick and Duffy study. All subjects were told to attend solely to the weapon signatures. Variations in meteorological conditions might have had an effect, but these data were not reported by Kushnick and Duffy. Photographs of the test site show that vegetation in the area was negligible. Therefore, variations in vegetation from subject to subject or time to time could not have been a factor. However, had there been vegetation, the acoustic signatures might well have been quite different. Garinther and Moreland also present data comparing the spectrum obtained at 80 meters with that obtained 2 meters from a weapon. It is obvious from the graphs presented that considerable wave form distortion occurred during the propagation over an open field. Exactly how the spectrum is influenced with increasing range is not specified. However, Garinther and Moreland do indicate that the differences are noticeable to the human ear.

Only one study was located which measured peak sound pressure levels down range. Garinther and Mastaglio[5] placed microphones down range at 115 yards, 315 yards, and 515 yards. Rounds were fired 10 feet over the microphones. They found that both peak sound pressure levels and durations were essentially constant from 115 yards through 515 yards. That is, peak SPLs varied by less than one decibel (dB). The peak for the M14 rifle was approximately 20 dB less than that measured near the muzzle. However, measurements at the muzzle, averaging 167.5 dB, were obtained from four feet from the left and right of the muzzle. The down range measurements, ranging from 147.1 to 147.8 dB, were obtained from the greater distance of 10 feet. A comparable decrement of 20 dB was also obtained for the AR 15, a .223 caliber weapon. Since the down range measurements were taken at a greater distance from the flight path, a lesser SPL would be expected. Unfortunately, Garinther and Mastaglio made no measurements 10 feet from the muzzle itself. Nevertheless, the loss in peak SPL down range appears not to be great. However, the duration of the impulse was shorter down range. For example, measurements of the duration four feet from the muzzle of the M14 varied from 3.0 to 3.4 milliseconds. The down range measurements varied from 1.0 to 1.1 milliseconds.

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[5] G. R. Garinther and G. W. Mastaglio. *Measurement of Peak Sound-Pressure Levels Developed by AR15 and M14 Rifle Bullets in Flight,* US Army Human Engineering Laboratories, Aberdeen Proving Ground, Maryland, January 1963.

Garinther and Moreland present some other data which appear to be highly relevant. In their effort to determine the characteristics of projectiles which minimize acoustic signatures, they found that projectiles which tend to yaw produce louder noises. One type of projectile they tested could be heard from only two or three meters at short ranges away from the muzzle. However, yaw began to increase down range from the muzzle, and at 150 meters down range it could be detected at much greater distances from the flight path. The authors attributed this to the shape of the projectile. Therefore, any tendency to yaw may be expected to alter the signature of a projectile rather markedly as it proceeds down range.

From the preceding discussion, it can be seen that a whole host of factors affect the down range signatures of passing projectiles. In other words, one must know what the meteorological conditions are, what type of terrain is being fired over, and what type (shape) of projectiles are fired before the acoustic signatures at any point down range can be known. Many of these factors were not reported by Kushnick and Duffy. However, even if they were, the data required to predict the exact signatures at 150 meters are simply not available. Therefore, it is impossible to know at the present time exactly what was heard by Kushnick and Duffy's subjects. Had their subjects been slightly closer or slightly farther away, or had meteorological conditions been different, the suppression indices obtained might have been different. As a result, it can only be assumed that the indices obtained are representative, and would remain relatively stable across a variety of ranges and meteorological conditions.

Despite the reservations implied in the previous discussion, and the general paucity of data on weapons signatures, the data reported by Kushnick and Duffy are worthy of further consideration. First of all, the question of the reliability of the indices should be examined. It can be noted in Table 2-2 that the variability of the ratings for each of the weapons was quite large in comparison to the mean. Generally, this indicates that the distributions were skewed, but it also indicates that there were wide differences in individual expectations of behaviors under fire. However, the means may still be quite stable, as each mean is based on a large number of observations.

Based on Kushnick and Duffy's work, both Winter and Clovis,[6] and Aiken, et al.,[7] employ kinetic energy as the nearest physical correlate

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[6] R. P. Winter and E. R. Clovis. *Relationship of Supporting Weapon Systems Performance Characteristics to Suppression of Individuals and Small Units*, TR 73/002, Defense Sciences Laboratories, Mellonics Systems Development Division, Litton Systems, Inc., Sunnyvale, California, January 1973.

[7] A. C. Aiken, W. L. Phillips, and D. V. Strimling. "Individual Suppression as Induced by Direct Fire Solid Projectile Weapons: Its Effect and Duration," (U), ARI paper, 30 April 1975.

of subjective loudness in attempts to develop models of suppression. It is interesting to note that Garinther and Moreland were also concerned with subjective loudness. They considered peak SPL, energy, impulse, and phons (ASA procedure) as correlates of loudness for subsonic projectiles. They concluded that impulse was the best measure, and that impulse was proportional to the cross-sectional area of the projectile. For supersonic projectiles they state:

> The primary factor which determines a supersonic projectile's loudness is the shock strength it generates. In turn, the strength of the shock wave depends primarily on the projectile's maximum diameter.

However, they do not provide a means for computing the subjective loudness of a subsonic projectile to place its value on the same scale as a supersonic projectile. Both Winter and Clovis, and Aiken, et al., assumed that Kinetic Energy (KE) was the correlate of loudness rather than diameter. Diameter is not necessarily proportional to KE as both total mass and velocity are involved. Nevertheless, it should be noted that the M60 projectile, with a KE x 10^{-8} of 3.63 received a perceived dangerousness rating of 41 (see Table 3-1). The AK 47 projectile, while having a KE x 10^{-8} of only 2.20, received a perceived dangerousness rating of 39. Both projectiles have a diameter of 7.62mm. The closeness of the psychological values provides some support to the notion that diameter is a primary factor in subjective loudness.

Table 3-1. Relationship Between Projectile Diameter, KE, and Perceived Dangerousness

Weapon	Projectile Diameter	KE x 10^{-8}	Perceived Dangerousness
Caliber .50	12.7mm	27.79	47
M60	7.62mm	3.63	41
AK 47	7.62mm	2.20	39
M16	5.56mm	1.33	37

Garinther and Moreland do not state that diameter and subjective loudness are linearly related. Certainly, a linear relationship between diameter and perceived dangerousness was not established by Kushnick and Duffy's work. A graph portraying the relationship between weapon and perceived dangerousness is presented in Figure 3-1. It is obvious that the .45 caliber weapon, which had the second largest diameter of those involved, was perceived as being among the least dangerous of the six weapons studied. The .45 caliber weapon was, of course, the only subsonic projectile among the six. Therefore, as can be seen from Figure

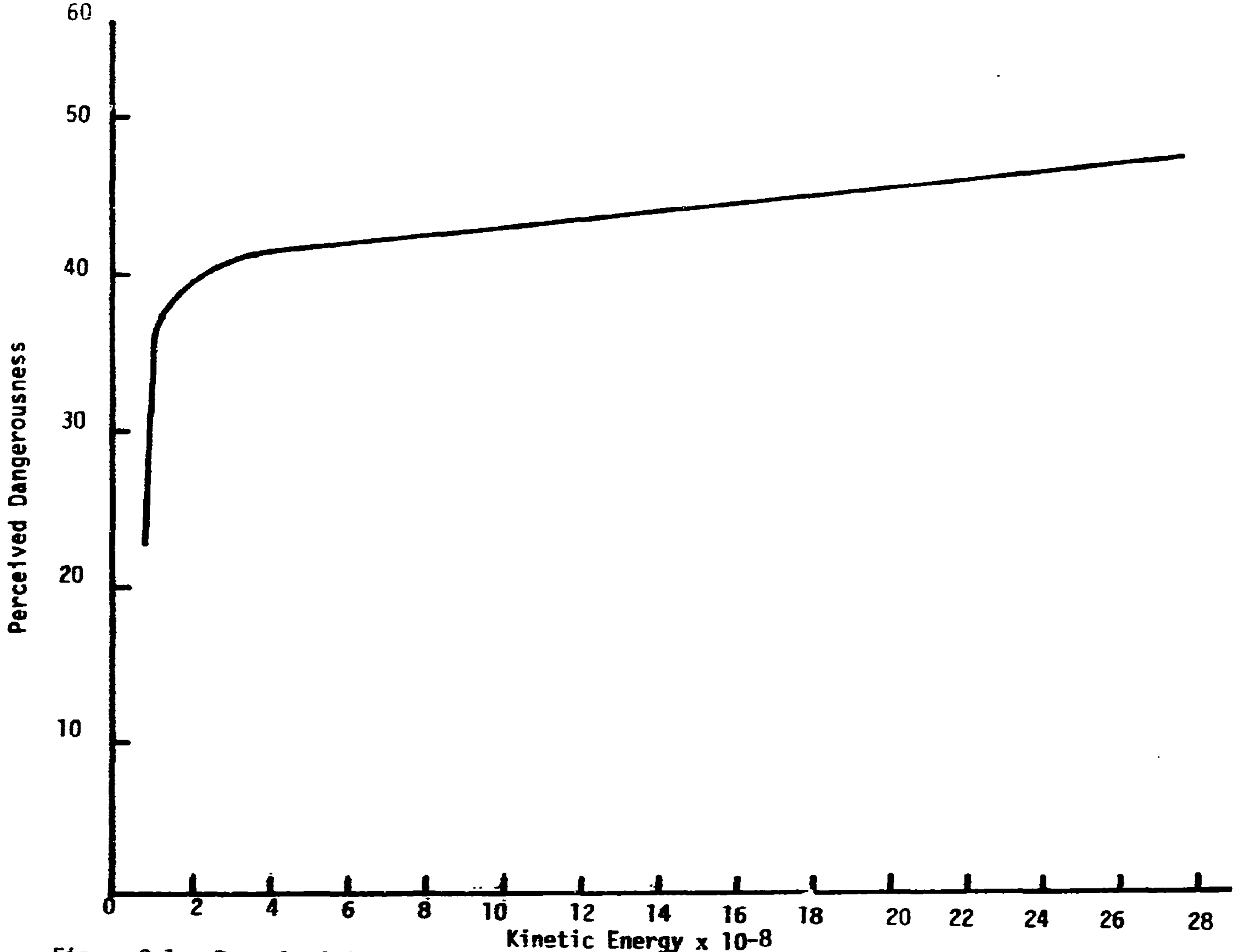

Figure 3-1. Perceived dangerousness as a function of kinetic energy (adapted from Kushnick and Duffy).

3-1, its position among the other weapons would not be a function of its diameter.

Although the signature data desired were not available, some further examination and analysis of the data presented by Kushnick and Duffy seemed warranted in light of other works. As was noted in Chapter 2, there were some apparent discrepancies between the conclusions drawn by the CDEC investigators[8] and the Litton investigators.[9] For example, the CDEC team found a logarithmic relationship between miss distance and suppressive behavior. The Litton team concluded, that within the limitations of their study, the relationship was linear. As pointed out in the previous discussion, this quite possibly could have been due to differences in the actual miss distances employed. However, a nonlinear relationship might have been postulated on a priori grounds. It is well known that the physical energy of an auditory stimulus decreases with the square of the distance from the receptor. Hence, on a priori grounds, one might expect a second degree equation to provide the best fit to miss distance data (see Figure 2-1, Chapter 2, page 2-10). Of course, exponential equations and second degree equations can take very similar forms. In either case, most of the curvilinearity tends to occur near the origin, or in this case, it would be expected to occur at the lesser miss distances. In the Litton studies, it is estimated that the observers were a minimum of approximately 3.5 meters from the passing rounds. This would place the minimum miss distance from the observer's ears on the more linear portion of the curve.

In the Litton studies, Kushnick and Duffy show a graph portraying the relationship between kinetic energy and the psychological variable of perceived dangerousness. This graph was shown earlier as Figure 3-1. The curvilinearity of the relationship is obvious from the graph. Kushnick and Duffy reported no attempt to fit a curve to the observed data. The shape of the curve, however, might have been expected, again on a priori grounds. It has been known since the days of Weber and Fechner that the relationship between physical and psychological scales tended to be exponential in nature. If kinetic energy is indeed directly proportional to the physical energy of the auditory stimulus, then an exponential relationship between kinetic energy and perceived loudness could be postulated. In any event, an attempt to fit an exponential curve to the data appeared to be worthwhile. Kushnick and Duffy do not report the perceived dangerousness ratings, so the values

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[8] Project Team II, US Army Combat Developments Experimentation Command, and Braddock, Dunn, and McDonald Scientific Support Laboratory, Fort Ord, California. *Dispersion Against Concealed Targets (DACTS), USACDEC Experiment FC 023*, Final Report, July 1975.

[9] Kushnick and Duffy, *op. cit.*

employed were read from the graph. The equation derived for predicting perceived dangerousness from KE x 10^{-8} is:

$$PD = \frac{\ln[(x-a)/b]}{c}$$

where $x = KE \times 10^{-8}$

$a = .927182$
$b = 4.28471 \times 10^{-7}$
$c = .382161$

A computed perceived dangerousness value was obtained for each of the six weapons employing the above equation. Table 3-2 lists the weapons, the kinetic energy of the projectiles as computed at 150 meters as computed by Kushnick and Duffy, the perceived dangerousness ratings read from Kushnick and Duffy's graph, and computed perceived dangerousness ratings obtained from the equation.

Table 3-2. Computed and Actual Perceived Dangerousness Ratings Based on Kinetic Energy

Weapon	KE x 10^{-8}	Actual PD	Computed PD
Caliber .50	28.00*	47	47.00
M60	3.63	41	40.97
AK 47	2.20	39	39.00
M16	1.33	37	35.99
Caliber .45	.93	27	23.01
XM 645	.94	23	26.97

*For ease in computation, 28.00 was substituted for the actual value of 27.97.

A correlation of $r = .96$ was obtained between the actual and the computed ratings. While a correlation of this magnitude is impressive, it must be remembered that the relationship was based on only six data points. Nevertheless, the psychological scale are means based on a large number of observations, and so should be relatively stable. Therefore, the result provides a reasonable indication that the perceived dangerousness of passing rounds, in the exact situation employed by Kushnick and Duffy, may be quite accurately predicted from a knowledge of the weight and velocity of the rounds.

Extrapolation of the curve obtained provides some interesting results. For example, the equation indicates that perceived dangerousness approaches 0 as KE x 10^{-8} approaches .927182. In other words, a

projectile with a KE only very slightly less than the caliber .45 would be predicted to have virtually no value in suppression. Similarly, a 20mm weapon would be predicted to have a perceived dangerousness rating of 49, only very slightly better than the caliber .50. Therefore, the results indicate that it would probably not be logistically efficient to employ any larger weapons in suppression. However, it must be remembered that the predictions made would probably be applicable only in the exact situation employed in the Litton study. Furthermore, it is very possible that the actual shape of the curve is ogival. That is, at some point below a KE x 10^{-8} value of .93, the curve may turn toward the origin so that a KE of 0 would result in a 0 rating of perceived dangerousness. Since no data are available on projectiles with lesser KE than the caliber .45, the actual shape of the curve below this KE is indeterminate.

A similar attempt was made to fit a curve empirically to the data for the Suppression Index. The data on kinetic energy are the same as shown in Table 3-2 and the SI ratings were taken from Table 2-2. The equation derived is shown below.

$$SI = \frac{\ln\left[(x-a)/b\right]}{c}$$

where $x = KE \times 10^{-8}$

$$a = .244383$$
$$b = .019885$$
$$c = .118728$$

The correlation between the observed and computed values of SI is r = .99. Again, the fit is excellent. Employing this equation, it would be predicted that a weapon with a KE x 10^{-8} of .264268 or less would not be suppressive at all. Similarly, a 20mm weapon would be predicted to have an SI value of 69. A weapon which would totally suppress return fires (see Response C, Table 2-1, page 2-2) would have to have an SI of 80, and a KE x 10^{-8} of over 260. The use of such a weapon for suppression hardly seems practical, and the weapon would hardly be considered a small arm. Therefore, again, it seems that the caliber .50 weapon is probably the largest caliber weapon that should be employed in a purely suppressive capacity.

Although the mathematical models fitting the observed values of the psychological scales and kinetic energy were excellent, it must be remembered that only six data points were involved, and three of these were employed in the empirical process of curve fitting. Nevertheless, the fit to the remaining points cannot be ignored. Only the M16 rifle fails to fall almost perfectly on the curves, and the deviation in either case is probably of no practical significance. Therefore, it has to be concluded that any further research into this area should first look at KE as a variable in predicting psychological responses to weapons. If the results hold, it should not be necessary to look further at

signature values of passing projectiles. KE may well take into account all critical aspects of the signature, at least for existing small arms. Of course, muzzle flash, muzzle blast, and impact signatures were not involved in the derivation of the equations, but, in circumstances where they are evident, will undoubtedly play a role in determining behavior.

The worth, valued against the cost, of doing further research in this area is a decision that must be reached by Army authorities. However, if further research is deemed to be warranted, it is recommended that the first step be an attempt to validate the usefulness of KE as the sole variable in predicting responses to passing projectiles. It is further recommended that a study of the relationship between KE and lethality be made, to assess the validity of the models which employ P_k (taking miss distance into account) as the primary determinant of suppression. Naturally, if possible, this effort should also consider blast, flash, and impact signatures singly and in combination with KE. All in all, such a program would be quite extensive in scope. As mentioned earlier, the desirability of such a program will have to be weighed against the desirability of other programs competing for limited funds. Nevertheless, the direction such a program should take, at least at first, seems clear.

Chapter 4

RECAPITULATION AND RECOMMENDATIONS

A primary purpose of this research was to determine, from information available, what aspects of the acoustic signatures of projectiles contribute to their being perceived as dangerous and/or result in suppressed behaviors. It was felt that no new data should be obtained at this time unless it could be shown that variation in the acoustic signatures of the various projectiles was indeed related to perceived dangerousness or suppressed behavior as reported by participants. Very little data on down range acoustic signatures could be found. However, such data would probably have not been useful in any case. Factors such as wind velocity and direction, temperature, humidity, vegetation, and distance from the muzzle have all been shown to affect at least some aspects of down range signatures. Therefore, unless all these conditions were knowns, data on acoustic signatures would probably not be of much value.

In further analysis of some previously reported data, kinetic energy, which is believed to be closely related to the perceived loudness of passing projectiles, appeared to account for nearly 100% of the variance between weapons in both a Suppression Index and a perceived dangerousness rating. Since kinetic energy at any given range from the muzzle can be computed relatively accurately from firing tables, this finding, if replicated, should prove useful in developing computer models involving suppression play. In the past, analysts have had to rely on intuition and/or fragmentary and possibly unreliable descriptions of battles and behavior under fire.

Although the use of kinetic energy appears to hold great promise for modeling suppression play, further research needs to be done. First of all, the general stability of equations derived needs to be determined. In other words, the results of the re-analysis reported in Chapter 3 need to be replicated. Moreover, additional work needs to be undertaken. The indices derived in the Litton studies were based on averages of ratings of several fire events. No means of partitioning the data to determine the effects of either miss distance or rate of fire on the scale scores is available. Additional work is needed to develop equations for various kinds of projectiles at various distances down range for each of several levels of miss distance and rate of fire. In addition, data on sound spectra, peak SPLs, and durations of the A and B waves should also be obtained. In the event that kinetic energy does not prove to be a reliable predictor of any scales employed such as the Suppression Index or the Perceived Dangerousness Index, an attempt could be made to relate these data to the scales derived.

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APPENDIX B

Executive Summary of SUPEX IIIB Final Report (USACDEC)

FOREWORD

1. AUTHORITY. Authority for the Suppression Experiment IIIB (SUPEX IIIB) was TRADOC approved on 21 June 1978.

2. CORRELATION. The SUPEX IIIB experiment is identified as CDEC Experiment FC 029G. Data from this experiment will be used to determine suppressive effects of static surface detonations on players when subjected to an open foxhole condition. These effects will be compared to the suppressive effects of static surface detonations on players when subjected to a closed foxhole condition. The results will be used to determine the feasibility of examining the suppressive effects of airbursts in future experimentation. Related studies previously conducted include:

SUPEX; Suppression Experiment, United States Army Combat Developments Experimentation Command, USACDEC, Fort Ord, CA, Feb 77.

3. CONTRACTUAL SUPPORT. Scientific Support Laboratory (SSL), USACDEC: BDM Scientific Support Laboratory (Department of the Army Contract Number DAAG-08-75-C-0105).

4. ACKNOWLEDGEMENTS. Field participation in support of the experiment was provided by the following agencies.

a. Player support from C Company, 2/31st Infantry Battalion, 7th Infantry Division, Fort Ord, CA.

b. Meteorological support from the Atmospheric Sciences Laboratory Meteorological Team, U.S. Army Electronics Research and Development Command, Fort Hunter Liggett, CA.

EXECUTIVE SUMMARY

1.1 PURPOSE. The purpose of Suppression Experiment IIIB (SUPEX IIIB) was to generate data and measure the reasoned suppression produced by statically detonated surface bursts of 60 mm mortar, 81 mm mortar, 105 mm howitzer, and 155 mm howitzer rounds. In addition, insights into physical suppression caused by obscuration were to be obtained.

1.2 EXPERIMENT DESCRIPTION.

a. Experiment Objectives. There were three experiment objectives. The first was to obtain data to determine the probability of suppressing (P(s)) an Antitank Guided Missile (ATGM) gunner with single rounds of the above mentioned ordinance as a function of detonation distance and aspect angle from the gunner. The second objective was to gain insights into the probability of suppressing an ATGM gunner with volley fires from 105 mm and 155 mm howitzers (surface burst). The final objective was to gain insights into the effect of obscuration on the probability of suppressing an ATGM gunner with the various type detonations. This objective was added to the test after the project analysis was published.

b. Player Actions. The player's mission was to maximize the number of target vehicle kills (HITS) while minimizing the number of times he was assessed as a casualty. Four players were placed in seperate, open foxholes in the center of the detonation area. Each player was to detect, track, and simulate engagement of a moving target vehicle with an antitank guided missile while simulated indirect fire rounds were statically detonated on the ground surface at various ranges and aspect angles from the player. After each detonation the player had to assess the hazard and assume one of the three postures. (Fully exposed, partially exposed, suppressed). If he remained in the fully exposed posture he could continue to track and engage the target but had the highest probability of becoming a casualty. If he remained partially exposed he could observe the target but could not engage it, and he had less probability of becoming a casualty. If he went to the suppressed posture he would not be assessed as a casualty, but could not observe, track or engage the target. Two seconds after the single round, and one second after the volley fire detonations, casualties were randomly assessed. The assessment probability of becoming a casualty was obtained from the Joint Munitions Effectiveness Manual. The probability of becoming a casualty included the variables:

(1) Player's posture.

(2) Range.

(3) Aspect angle to the detonation, and

(4) Size of the detonation.

The player's reactions to the detonations were automatically recorded and time coded by the Data Acquisition and Recording System (DARS) and by Closed Circuit Television (CCTV). The data were then analyzed to determine the effects of the detonations on the players ability to perform the assigned mission.

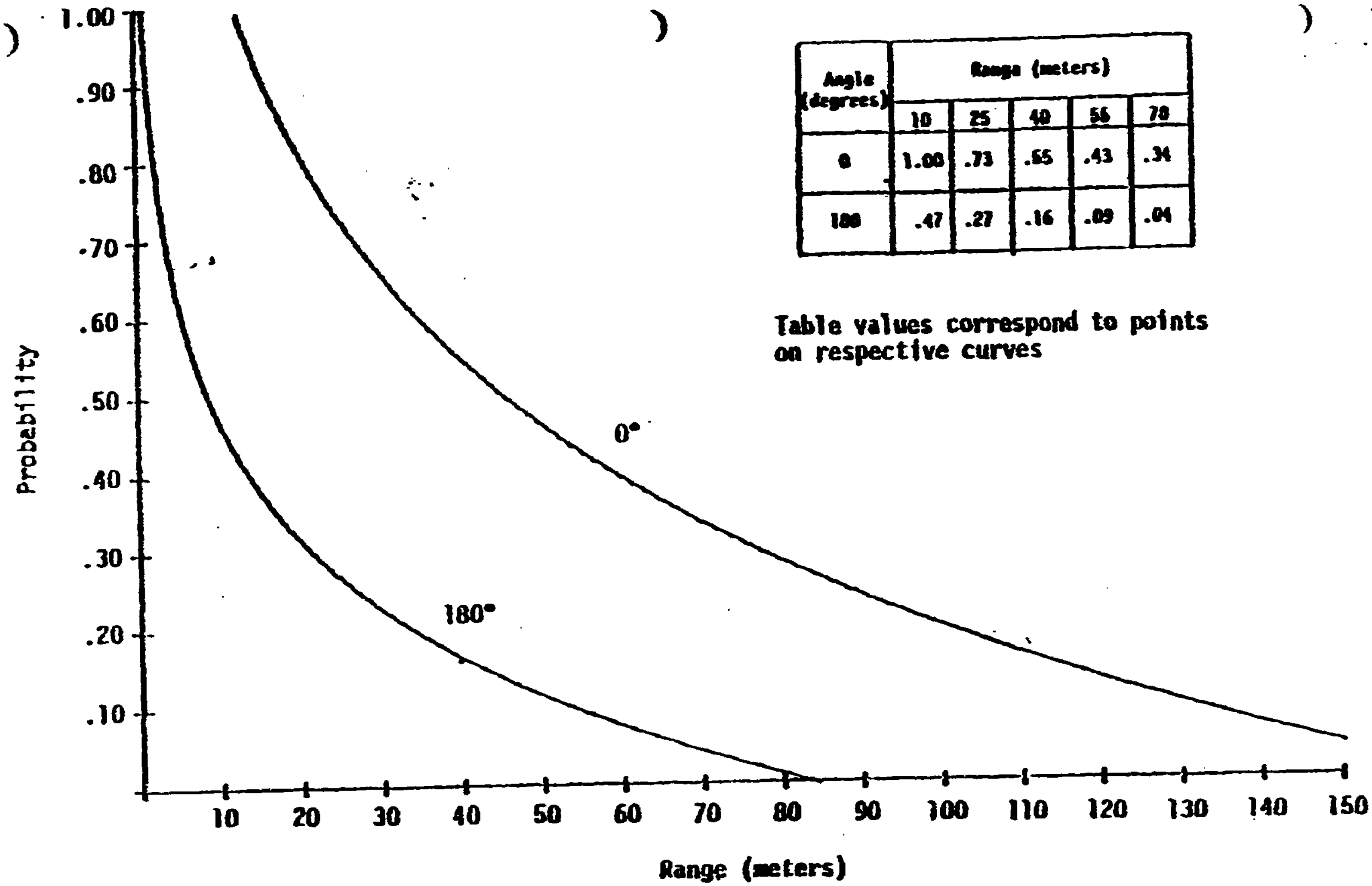
1.3 MAJOR FINDINGS.

a. Single Round Detonations. For any given range and round size, the most suppressive detonations observed were directly in front of the player (0 degrees). The observed least suppressive detonation varied for each round size but was always behind the player. (The least suppressive aspect angle for 60 mm, 81 mm, 105 mm, and 155 mm was 180, 150, 180, and 210 degrees, respectively.) According to player reports, this variation in suppression was due to the lack of visual information available to them from detonations occuring behind them. The players indicated they used this visual information in conjunction with aural information to decide whether to assume a suppressed posture, and if the visual cue was not available, they were inclined to remain in the least suppressed posture. The fitted curves for the most and least suppressive angles of detonations are presented in Figures 1 through 4 for each round size. For example, the curves in Figure 1 indicate that if a 60 mm mortar shell was detonated 50 meters from a player, the probability of his being suppressed by the detonation would be .47 if the shell exploded in front of him (0 degrees) and .11 if it exploded behind him (180 degrees). Since artillery and mortar detonations occurred on different trials, it is inappropriate to compare the data presentation in the figures for mortar detonations with those for artillery detonations. The values of these curves corresponding to the ranges used in the experiment are also presented in each of the figures.

b. Volley Round Detonations. The most suppressive detonations during the volley fire were located to the player's front (0 degrees) and the least suppressive detonations were generally at 90 or 180 degrees. Again, the players reported that this differential suppressive effect was due to the relative lack of visual information provided by detonations outside their field-of-view. The observed data for the most and least suppressive angles for each round size are presented in Tables 1 and 2. Table 1, for example, displays an observed probability of suppression of .88 at an angle of 0 degrees (directly to the player's front) for a 105 mm volley detonated at a range of 85 meters. Because of the investigative nature of volley fire, these data were not fitted to exponential curves. In comparing the suppressive effects of single round and volley fire the following results appear. At similar ranges the volley fires appear to be more suppressive than single rounds. For 105 mm volley fires the observed probabilities of suppression went from 1.0 at 45m to .35 at 125 meters. Over similar ranges the single round probabilities of suppression varied from .55 to .08. Similar results were observed with the 155 mm detonations.

c. Obscuration. For single round detonations, when obscuration of the target vehicle was reported, the angle between the target vehicle and the detonation measured from the players' vantage point was generally between ±45 degrees. Some players stressed that during periods of obscuration, they modified their tracking strategies depending on the density and dispersion of the obscuring cloud. If the cloud covered too wide an angle of view and/or remained for a considerable period, the player went into a suppressed posture. According to player questionnaire responses, target obscuration was second only to the detonations themselves as an important determinant of suppression. The players stated they adopted a fully suppressed posture to avoid being assessed as a casualty when the obscuring dust/smoke cloud prevented them from tracking the target vehicle.

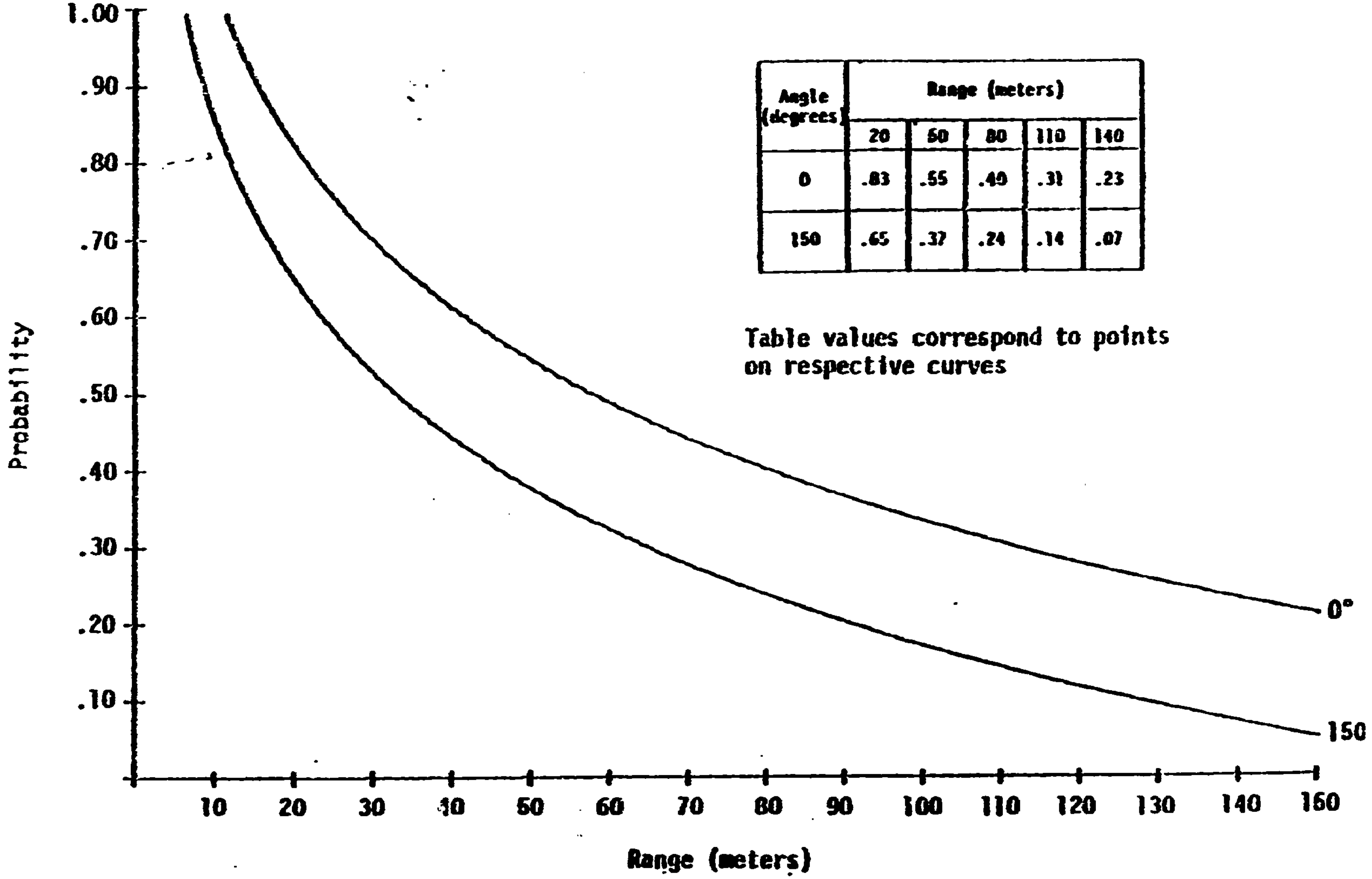
d. Training Benefits. Human Factors questionnaire results and individual interviews showed that the players regarded the experiment as very realistic training, particularly during the volley trials. The experiment provided 7th Infantry Division player and support personnel with realistic sights and sounds of the "dirty battlefield." This realistic training experience enhanced player motivation throughout the experiment.



Angle (degrees)	Range (meters)				
	10	25	40	56	78
0	1.00	.73	.65	.43	.34
180	.47	.27	.16	.09	.04

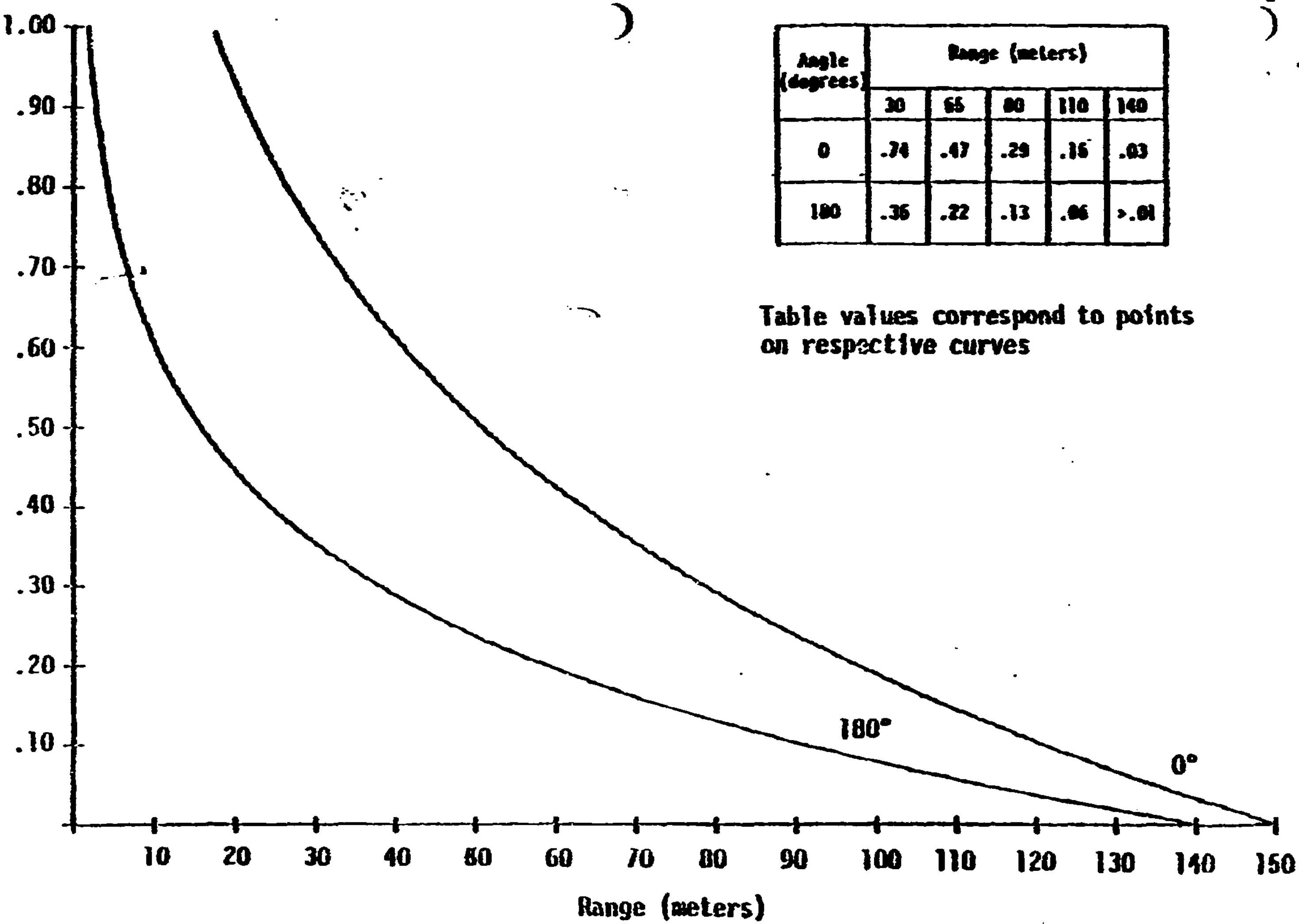
Table values correspond to points on respective curves

Figure 1 PREDICTED PROBABILITY OF SUPPRESSION FOR 60 MM AT 0 AND 180 DEGREES - SINGLE



Angle (degrees)	Range (meters)				
	20	50	80	110	140
0	.83	.55	.40	.31	.23
150	.65	.37	.24	.14	.07

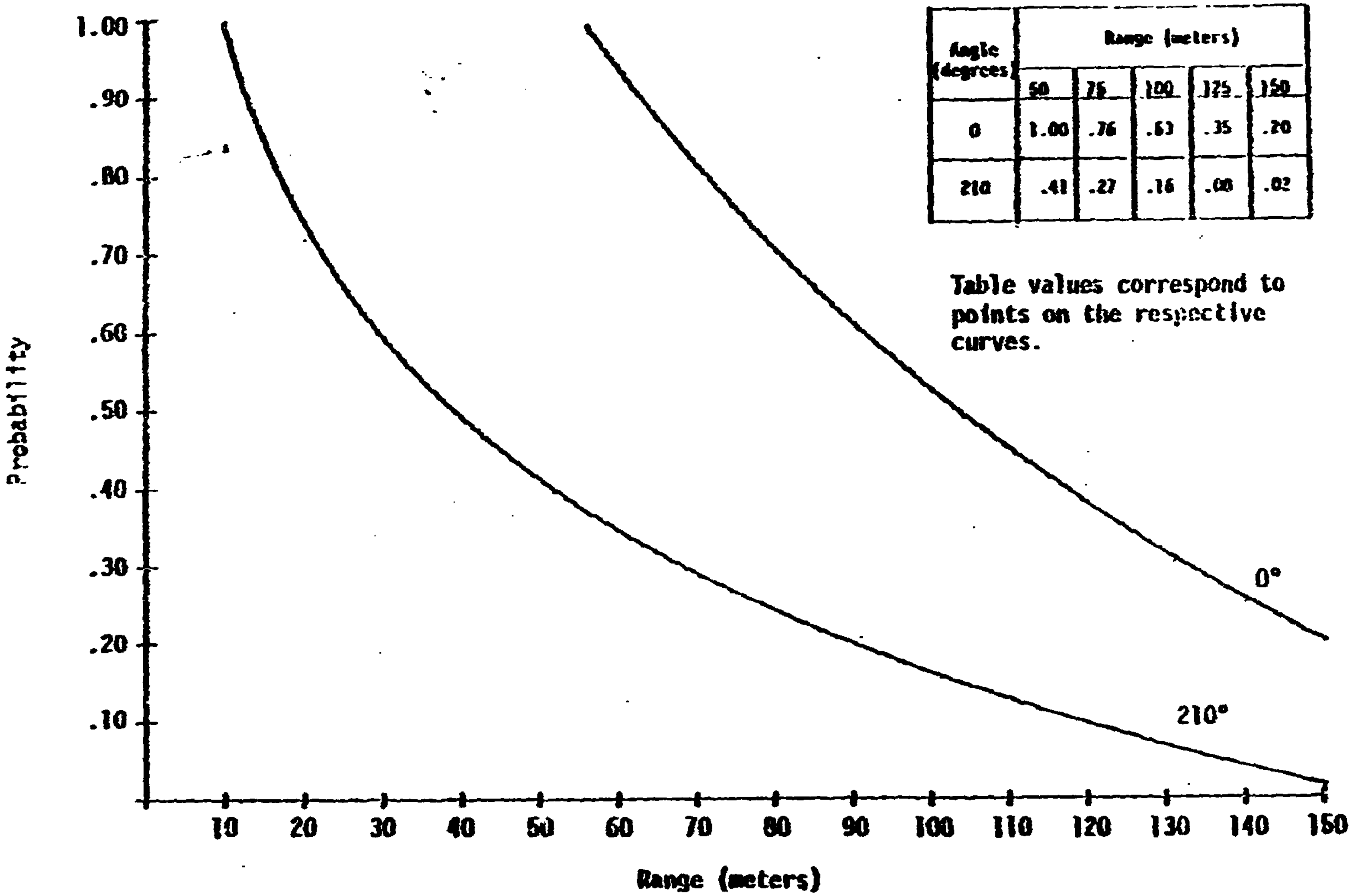
Figure 2 PREDICTED PROBABILITY OF SUPPRESSION FOR 81 MM
AT 0 AND 150 DEGREES - SINGLE



Angle (degrees)	Range (meters)				
	30	65	80	110	140
0	.74	.47	.29	.16	.03
180	.36	.22	.13	.06	>.01

Table values correspond to points on respective curves

Figure 3 PREDICTED PROBABILITY OF SUPPRESSION FOR 105MM AT 0 AND 180 DEGREES - SINGLE



Angle (degrees)	Range (meters)				
	50	75	100	125	150
0	1.00	.76	.53	.35	.20
210	.41	.27	.16	.08	.02

Table values correspond to points on the respective curves.

Figure 4. PREDICTED PROBABILITY OF SUPPRESSION FOR 155MM AT 0 AND 210 DEGREES - SINGLE.

TABLE 1 PROBABILITY OF SUPPRESSION AT THE MOST SUPPRESSIVE ANGLES OBSERVED FOR EACH RANGE FOR THE 105mm - VOLLEY

	Range (meters)		
	45	85	125
	Probability / Angle	Probability / Angle	Probability / Angle
Most Suppressive Angle	1.00 / (0)	0.88 / (0)	0.33 / (0)
Least Suppressive Angle	0.63 / (90)	0.14 / (180)	0.11 / (90&180)

TABLE 2 PROBABILITY OF SUPPRESSION AT THE MOST SUPPRESSIVE ANGLES OBSERVED FOR EACH RANGE FOR THE 155mm - VOLLEY

	Range (meters)		
	65	105	145
	Probability / Angle	Probability / Angle	Probability / Angle
Most Suppressive Angle	1.00 / (0)	0.78 / (0)	0.50 / (0)
Least Suppressive Angle	0.86 / (270)	0.20 / (90)	0.14 / (180)

DEPARTMENT OF THE ARMY
HEADQUARTERS UNITED STATES ARMY TRAINING AND DOCTRINE COMMAND
FORT MONROE, VIRGINIA 23651

ATCD-AN-C

02 FEB 1979

SUBJECT: SUPEX IIIB Final Report

SEE DISTRIBUTION

1. The SUPEX IIIB study has been reviewed by Headquarters TRADOC.

2. The SUPEX IIIB experiment is a significant step forward in realistically quantifying the effects of indirect fire suppression.

3. Because of what appears to be contradictory results between mortar and artillery trials, caution should be exercised if these data are considered for use in models and simulations.

4. Future experimentation programs envision follow-on experiments to produce more consistent mortar and artillery data.

FOR THE COMMANDER:

Doreatha Mangrum

DOREATHA MANGRUM
Assistant Adjutant General

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APPENDIX C

Indirect Fire Suppression Model

By

Phillip M. Allen (AMSAA)

TITLE: Indirect Fire Suppression Model

AUTHOR: Mr. Philip M. Allen

ACTIVITY: US Army Materiel Systems Analysis Activity, Aberdeen Proving Ground, Maryland

I. INTRODUCTION

A. Special Projects Branch of the Ground Warfare Division, US Army Materiel Systems Analysis Activity, is presently developing jointly with the Royal Armament Research and Development Establishment (RARDE) of the United Kingdom a simulation of combat at battalion level. This simulation is stochastic and employs the event sequencing technique.

B. A full representation of combat effects is to be portrayed within the simulation. Accordingly, a representation of suppression caused by both direct fire and indirect fire systems is to be generated.

C. This paper addresses the potential representation for the indirect fire case. A definition of terms is given along with the methodology proposed. The methodology described is a development of a RARDE model on an analysis of British data on artillery effectiveness from several allied invasions during World War II.

II. DEFINITION OF SUPPRESSION

A. Suppression is often confused by being the result of two phenomena, viz, the fear of and reaction to a perceived threat caused by the detonation of indirect fire munitions and the non-lethal physical effects of the detonation of such munitions.

B. Within the AMSAA/RARDE combat simulation, these two phenomena are to be separately represented, the former only being termed suppression. The degradation of sensor systems caused by the dust and smoke of artillery round detonation is to be quantified and represented as a separate effect.

C. Thus, suppression is defined to be the effect on a system caused by the perception of a threat by that system's operators. The threat in this paper will be taken to be the detonation of indirect fire munitions.

III. DEFINITION OF SUPPRESSION EFFECTS

A. When a military system is suppressed, it is necessary to relate this fact to an effect on that system's ability to undertake its intended functions in combat. Suppression is not taken to mean that the system becomes completely inoperable for a period of time; the assumption made is that a degradation in function performance results, each function being affected in a different way.

B. The functions which it is contended will be effected are those of detection, firing, and movement. These are discussed separately.

C. Detection

1. Three situations should be differentiated in this category. They are:

(a) A new detection generated from the normal search process.

(b) Retention of a previous detection.

(c) Detection caused by weapon signature.

The relationship of suppression effects to each of these three areas is discussed separately since different considerations are necessary.

2. New Detection from Normal Search Process. When attempting to detect targets the observer will, when suppressed, be unable to undertake the normal search process so efficiently. There will be periods during which no observation is being made, but such periods are thought not to be of significant duration. However, when suppression effects become zero, the search process will be resumed at full efficiency.

The representation of suppression effects on this combat function will be taken as a reduction in the detection rate parameter associated with the log-normal distribution of time to detect. However, if the suppression duration exceeds a specified maximum time, t_{max}, all information collected on potential targets is lost, and all scheduled detections must be cancelled.

3. Retention of a Previous Detection. In this case, the representation to be used is that if the observer is suppressed for a period of time exceeding t_{max}, as defined in Section III, Part C, paragraph 2, the detection will be lost; reacquisition being made under the normal search process or by launch signature detection.

The rationale behind this representation is that, after a certain time period, the observer will have to reorientate himself to his area of responsibility, having lost his mental picture while being suppressed.

4. Weapon Signature Detection. The detection of a weapon launch signature and acquisition of that weapon as a target can be characterized as being stimulated by an awareness of a flash and/or dust and smoke and, from this information which essentially restricts an observer's search area, characterized by detection from the resulting search process.

Thus, when a unit is suppressed, it is likely that the initial cue of the flash and/or initial dust and smoke cloud growth will be less readily observed. Although the dust and smoke cloud may be visible, the source point will not be so obvious resulting in the detection being less likely.

The representation of this situation is proposed as a reduction in the probability of detection when the observer is suppressed.

D. Firing

1. This situation occurs when the decision to engage a target has been made and the loading and laying process is being undertaken.

2. It is unlikely that the loading phase of an engagement will be affected by suppression since it is assumed that weapon systems in a direct fire battle will be reloaded directly after undertaking an engagement.

3. The laying process, however, may be affected since the crew member responsible for this process can be suppressed. The effect is likely to be a less accurate lay being achieved.

4. Thus, the proposed characterization of suppression effects is to be a reduction in the probability of hit, but no increase in the time to complete the loading and laying process. The degradation in hit probability will be a function of the level of suppression which occurs. However, to prevent the situation arising in which a unit fires many rounds with extremely low accuracy due to suppression effects, an engagement is to be aborted if a threshold suppression level is reached. This level is to be that at which a previous detection is lost as described in Section III, Part C, paragraph 3. (Although Section III, Part C, paragraph 3 refers to suppression time, it is possible to relate that time to a particular suppression level since both suppression level and duration are calculated from the volley density. See Parts B and C of Section V).

E. Movement

1. Two situations need to be differentiated in consideration of this combat function. These are units which are moving and those which are stationary.

(a) Stationary Units. The representation to be used in this situation is that all stationary units remain in that state while suppressed. For both defending units and attacking units in an over-watch role, it is considered that they will remain at their location and attempt to undertake their assigned missions while suppressed.

For attacking units in covered positions away from detection by enemy units, it is assumed that they take a posture which reduces suppression effects. Further, however, since they are in an out-of-combat state, they remain in this state until suppression effects cease and may then rejoin the battle. The suppression effects in this case are only those of delay on the suppressed units.

For units which have stopped to fire at the short halt during a movement phase, they will be deemed to stop for as long as it takes to fire one munition and then to behave as a moving unit while encountering suppression effects.

(b) Moving Units. A unit suffering suppression effects while moving will be assumed to increase speed to its maximum and continue to undertake its mission. If, however, a mixed unit of say tanks and APCs is moving, the maximum speed is defined as the minimum of the maximum speed of each constituent element in order that the unit maintains cohesion.

The rationale here is that as much relief from suppression effects may be gained by continuing towards a unit's objective as can be obtained from any other course of action since the ease of re-direction of the deliverying artillery tubes' aim points is independent of the moving units' direction of movement. Further, as the units close with the enemy, the munitions causing the suppression may have to be terminated to prevent damage to friendly forces.

IV. DIFFERENTIAL EFFECTS OF SUPPRESSION ON UNITS

A. Section III above describes the general way in which suppression effects will be generated within the model and the rationale behind the representation. However, no account was made of the difference in a particular effect between different types of units. For example, a tank will not be affected in the same way as an infantry squad when searching for a target while under similar suppression conditions. Moreover, the suppression effects will be a function of the actual vehicle type as opposed to the generic vehicle class. For example, an XM1 tank may be differently affected than an M60 tank simply because of the design differences of the systems causing operation in a suppression environment to be easier in certain cases.

B. In consequence, the methodology developed represents this feature by a function suppressibility factor. This factor is a function of the vehicle/unit and varies with the individual functions described in Section III.

C. To obtain values for this factor, it will be necessary to investigate the processes by which the various unit functions are achieved.

1. The field of view of the sensor systems will be of importance in this context since the visual cue of detonating artillery munitions is likely to be the main stimulus for suppression.

2. Since suppression is likely to be affected by the vulnerability of the unit to artillery munitions, this will also have to be considered.

3. The ability to command a unit in a suppression environment also will affect the factor. For a tank, the effect of operating in a closed down or semi-closed down mode must be represented since the commander will not be able to perform all of his functions so efficiently under such conditions.

These are just three of the areas to be considered in the generation of values for this parameter which are felt to be essential if a suppression representation which differentiates between vehicles within

a generic category and between different types of units is to be generated.

V. METHODOLOGY

A. Representation of Indirect Fire Engagements

The method of representation of all indirect fire engagements is that all consequent effects are assessed at the impact of each volley fire and not as a total effect of a complete engagement. In consequence, suppression effects will be represented at the impact of each volley.

The area which is affected by each volley is a number of 100 meter squares which are assessed for effect independently. Thus, a munition detonating in one 100 meter square will have no effect on an adjacent area. This methodology will apply similarly in the suppression representation.

The volley density within a 100 meter square is the basis for determining the suppressive effects of the volley upon units in that square. The precise methodology for calculating the suppressive effects generated by a single volley is described in Section V, Part B. A suppression time interval is also calculated and a target will remain suppressed at the time level during this interval unless another volley impacts in the vicinity of that target. If no additional volleys are received, the target becomes unsuppressed at the end of that interval. Section V, Part C, describes the method of obtaining the suppression time interval. As additional volleys impact in the vicinity of a target, the cumulative effect of those volleys is considered, as described in Section V, Part D.

B. Calculation of Suppressive Effect for a Single Volley

When a volley is delivered, the density of rounds in each 100 meter square is determined. This density is then converted to standard units (equivalent 105mm HE rounds) by multiploying by the lethal area of the shells in the volley and by a conversion constant to represent the lethal area of the 105mm HE round. This standardized density (d) is used to define the suppressive effect of a volley (SE) by comparison with the threshold at which initial suppression occurs (d_1), as derived from the World War II data used. The methodology is

$$SE = 0 \text{ if } d \leq d_1 \qquad \text{(No Suppression)}$$

$$SE = \frac{1}{2(d_2 - d_1)} \times (d - d_1) \text{ if } d_1 < d < 2d_2 - d_1$$

(Partial Suppression)

$$SE = 1 \text{ if } d \geq 2d_2 - d_1 \text{ (Total Suppression)}$$

The computation is simply the result of first assuming that suppression increases linearly from 0 to 1 as density increases from d_1 to d_2. Then, since the value SE will be assumed by the simulation to remain constant for the duration of the suppression time interval, the calculated level is reduced by 50% to compensate for the actual continuous reduction of suppressive effect which takes place during the suppression time interval.

C. Duration of Suppressive Effects.

The duration (t_s) during which the unit is suppressed, i.e., the time for the value of d to decay to d_1, is calculated using the assumption that the effects decay exponentially. That is

$$d_1 = d\, e^{-\alpha t_s}$$

which yields

$$t_s = -\frac{1}{\alpha} \ln (d_1/d)$$

The constant α must be specified by input (assuming $t_s = 30$ for $d = \frac{d_1 + d_2}{2}$ is a possible method for selecting the value of α).

D. Suppressive Effects of Subsequent Volleys

The problem of determining the cumulative suppressive effect of two or more volleys is addressed here.

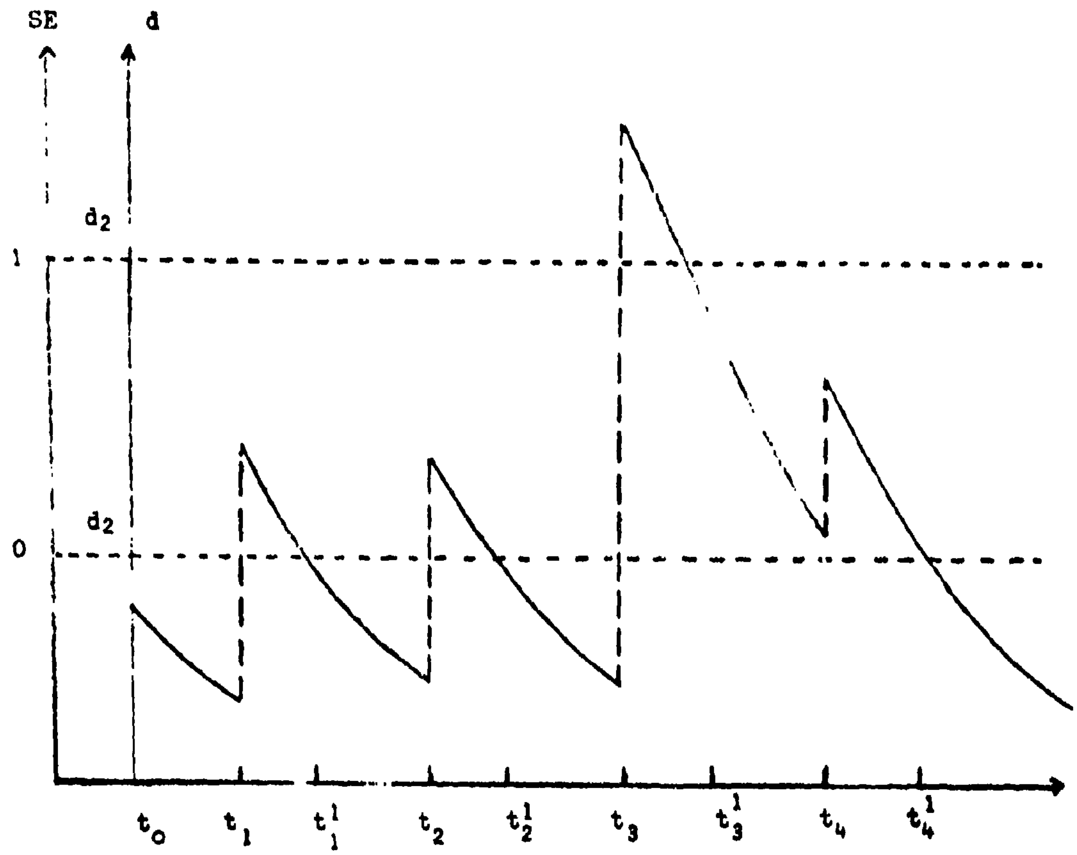
Assume that the time of occurrence, t_o, and the density, d_o, of the most recent volley with respect to a given unit are calculated. The density, d, of the next volley, occurring at time t^1, is calculated independently as per Section V, Part B. This density is accumulated into the residual effect of the previous volley to give an effective density, d^1, by

$$d^1 = d + d_o\, e^{-\alpha \Delta t}$$

for $\Delta t = t^1 - t_o$

The value of SE is calculated from d^1 as per Section V, Part B and the duration of the suppressive effects as per Part C.

The following graph represents a history of densities calculated for several volleys. The length of the dotted line represents the actual density of each volley.



Volleys are fired at times t_o, t_1, t_2, t_3 and t_4. The representation above gives that the unit was partially suppressed from t_1 to t_1^1, t_2 to t_2^1, t_3^1 to t_4^1 and totally suppressed from t_3 to t_3^1. The value of SE would be calculated as 1 for time t_3 to t_3^1, 0 from t_o to t_1, t_1^1 to t_2, t_2^1, to t_3, and from t_4^1 and an intermediate value between these times. Thus, if a value of SE was calculated at time t_2, this level of suppression effect would be assumed to stay for the period t_2 to t_2^1. It should be noted that once a unit has been suppressed, it will always have some residual density since a simple exponential decay is assumed.

VI. APPLICATION OF SUPPRESSIVE EFFECTS. The suppressive effects are applied to the functions of the unit as described below and summarized in the next table.

A. Detection

For a detection, the detection rate λ, is reduced by the factor (1-K.SE), SE as described in Section V (Part B) and K as described in Section IV.

For a unit already detected, the detection is lost if t_s exceeds a specified value.

For a launch signature cue generated during the observer's suppressed period, the probability of detection is reduced by the factor, 1 - K.SE for K as specified in Section IV and SE as in Section V (Part B).

B. Movement

All stationary units remain stationary for time t_s. All moving units accelerate to maximum speed for time t_s.

D. General

By selection of suitable value of K, the effect of suppression on a particular unit function may be set to zero.

SUMMARY OF SUPPRESSIVE EFFECTS

DETECTION

(1) Future detection — Detection rate → Detection rate (1-K.SE)

(2) Already detected — Lost if t_s > specified value

(3) Launch signature — Detection prob → Detection prob (1-K.SE)

FIRING — P(HIT) → P(HIT) X (1-K.SE)

MOVEMENT

(1) Stationary — Remain in that state for time t_s

(2) Moving — Accelerate to max speed for time t_s

APPENDIX D

Review and Evaluation of Current Suppression Models with Proposal for Interim Model

By

Phillip M. Allen (AMSAA)

GROUND WARFARE DIVISION

INTERIM NOTE G-45

REVIEW AND EVALUATION OF CURRENT SUPPRESSION MODELS WITH PROPOSAL FOR INTERIM MODEL

Philip M. Allen

May 1977

Approved for public release; distribution unlimited

US ARMY MATERIEL SYSTEMS ANALYSIS ACTIVITY
ABERDEEN PROVING GROUND, MARYLAND

G R O U N D   W A R F A R E   D I V I S I O N

INTERIM NOTE G-38

PMAllen/lfw
Aberdeen Proving Ground, MD
May 1977

UNCLASSIFIED ABSTRACT

A synopsis of several current suppression models and field tests is presented together with an assessment of their relative strengths and weaknesses. These sources are then combined to serve as a basis for formulating an interim suppression model to be used in existing high resolution force-on-force models.

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REVIEW AND EVALUATION OF CURRENT SUPPRESSION MODELS WITH PROPOSAL FOR INTERIM MODEL

. INTRODUCTION

1.1 Objectives.

One purpose of this study was to review the current models for suppression, along with the data currently available, and combine this information into a synopsis of each of the models and their relative strengths and weaknesses. In connection with this objective, a meaningful comparison of the available models for realistic combat situations was planned.

The second objective was to draw from the available sources a model for recommendation as an interim suppression model to be implemented into high resolution combat simulation programs. This model should be revised or replaced as the general knowledge in the area of suppression is extended and a greater volume of significant data is made available. The development of the model was planned to include three major aspects of the suppression phenomenon.

a. Probability of becoming suppressed in a given time interval.

b. Effects of suppression on movement, acquisition, and firing.

c. Duration of suppression.

1.2 Background.

There has been considerable interest recently in the modeling of suppression, particularly since the release in April 1976, of data from a series of field experiments on suppression conducted by the US Army Combat Developments Experimentation Command (USACDEC)(Reference 1). The USACDEC data appeared to differ widely from the suppression values predicted by the Litton model, which is currently being used in the AMSAA War Game (AMSWAG). Because of this and other questions about the validity of the Litton model, there is a need to revise it or to develop a new suppression model for implementation into AMSWAG. Since there are several suppression models currently in use in other combat simulation programs, there is also a need to evaluate them and make comparisons of the values they predict for realistic combat assumptions. The most desirable characteristics of each may then be determined and used in any future modeling efforts.

1.3 Scope.

A major emphasis was placed on four of the models considered: The Litton model, the Army Small Arms Requirement Study (ASARS) model, the RARDE model (developed by the Royal Armament Research and Development Establishment of the United Kingdom), and the model developed from the

CDEC field test data. These were compared and evaluated extensively. Other models were given less emphasis, and due to the unavailability of detailed information on some of them they were not compared and evaluated as completely. These include the suppression models used in DYNTACS, JIFFY, CARMONETTE, and the Naval Weapons Center combat simulation, and models proposed by Horrigan Analytics and Vector Research, Inc.

Following the review and comparison of existing models, a new suppression model was developed and recommended for use in AMSWAG. It consists of a combination of the ASARS, CDEC, and RARDE models with some modifications, as described in Section 4. The need to fill gaps in the data on suppression was recognized, and recommendations are made in Section 5 for filling those gaps.

2. REVIEW OF EXISTING MODELS

In this section a synopsis of each of several suppression models used in various combat simulations (or proposed for implementation) is given, with a brief assessment of their relative strengths and weaknesses. Some of the descriptions are more general than others due to the lack of detailed information available. Where possible, the descriptions include the method of computation of suppression, the effects of suppression, and the duration of suppression.

2.1 The Litton Model as Used in AMSWAG.

Probability of suppression, P(S) in the Litton model (Reference 2) is a function of the expected fraction of casualties ($\bar{f}$) during some time interval Δt and a human factors coefficient (ρ) which is used to account for individual variance in vulnerability to suppression. A value of 1.0 to ρ corresponds to the "average" soldier, with higher values of ρ corres- tc more easily suppressed individuals and lower values corresponding to individuals who are more difficult to suppress. Suppression of vehicles has also been considered by using appropriately small values of ρ. The formula for suppression is:

$$P(S) = \frac{e^{\beta}}{e^{\beta} + 1},$$

$$\text{Where } \beta = 10 \exp \left[(-0.04/\rho)\left(\frac{(1-\bar{f})^2}{\bar{f}}\right)\right] - 5$$

The Litton model itself does not predict the effects of suppression or the duration of suppression. However, in AMSWAG suppression affects firing (does not affect movement or acquisition). The value of P(S) is interpreted as the fraction of a unit suppressed. That fraction of the unit continues to fire, but causes no attrition. For duration of suppression, the following formula is used:

$$y = e^{-\Delta t/\mu_s},$$

where y is the probability that a suppressed unit remains suppressed after time Δt and μ_s is an input mean duration of suppression (usually 10 seconds for vehicles and 15 seconds for personnel).

A major advantage of the Litton model is that the inputs required are simple and easily accessible. Also, the use of $\hat{f}$ takes into account a variety of weapon and target characteristics. However, the dependence of the model on $\hat{f}$ tends to make it extremely sensitive to small changes in $\hat{f}$ (e.g., for $\rho = 1.0$, as $\hat{f}$ varies from .03 to .05, P(S) varies from .11 to .47). Also, it is possible that two weapons with similar effectiveness data would have different suppressive capabilities, due to aural and visual cues, but the Litton model would not reflect such a difference.

2.2 The RARDE Suppression Model.

The RARDE/AMSAA model is a high resolution combat model being developed jointly by AMSAA and RARDE, of the United Kingdom. The information on the RARDE model was obtained from a published British report (Reference 8). The suppression submodel developed by RARDE considers direct fire suppression and indirect fire suppression separately. For direct fire suppression of personnel, use of the Litton model is proposed. Direct fire suppression of vehicles is caused by a lethal or non-lethal hit on the vehicle. For indirect fire, it is assumed that suppression is a function of the intensity of fire (I, measured in rounds/hectre/minute) placed in the target area. The basis for the equation used is a British report based on an analysis of WWII data for unprotected soldiers in which intensities of indirect fire required for marginal suppression and for total neutralization were given. RARDE converted these intensities to pounds of equivalent 105mm shells/100 meter square/min (I') and arrived at the values of I'=.11 for the onset of suppression and I'=.46 for total neutralization of unprotected personnel. It is assumed that suppression exhibits a linear relationship to I' with P(S)=0 for I'=.11 and P(S)=1 for I'=.46. The equation for converting I to I' involves the lethal area (LA) of the firing weapon as follows:

$$I' = I \times (LA) \times 1.06 \times 10^{-3}$$

The resulting equation for suppression is then:

$$P(S) = 2.857 \times I' - .314, \quad .11 \le I' \le .46$$

This value, P(S), is not actually called probability of suppression by RARDE, but is instead, directly interpreted as the fractional reduction in target acquisition, hit capability, and movement for dismounted infantry. For vehicles, a slightly different formula is used, based on the same threshold intensities, but depending on the duration of bombardment. Target acquisition and movement are affected by indirect fire

suppression of vehicles. The RARDE model also considers demoralization for extremely intense bombardments of indirect fire on personnel. Demoralization has the effect of prolonging the suppressive effects of indirect fire.

An advantage of the RARDE model is that it distinguishes between direct and indirect fire and models them differently. The inputs required (fraction of casualties, lethal areas, and intensity of indirect fire) are not extremely involved, and the equations are simple. However, the use of linear relationships for indirect fire suppression may be open to question, since no justification is made for that assumption.

2.3 The CDEC Model.

A series of field experiments was conducted by CDEC for both direct fire and indirect fire suppression. Suppression was assumed to follow a logarithmic function of the form

$$P(S) = \frac{1}{B} \ln \left(\frac{RMD}{A}\right),$$

where RMD is the radial miss distance of a given round. (Reference 1). A regression was performed from the field test data for each weapon included in the experiment to determine the values of the parameters A and B. Some examples of the values derived are as follows:

Direct Fire

	M3	M16A1	M60	M2	M139
A	41.724	42.719	89.556	160.940	674.37
B	-5.549	-5.086	-5.395	-3.740	-4.860

Indirect Fire (Ground Burst)

	60mm Mortar	81mm Mortar	4.2in Mortar	105mm Howitzer	8in Howitzer
A	65.482	183.800	213.840	304.990	1120.78
B	-11.2799	-1.8674	-1.740	-1.8960	-2.1009

Indirect Fire (Air Burst)

	4.2in Mortar	105mm Howitzer	155mm Howitzer	8in Howitzer
A	274.10	278.30	366.14	1310.03
B	-1.60	-1.40	-1.44	-1.99

Since the experiments were designed only to measure probability of suppression, the CDEC model makes no predictions concerning effects or duration of suppression.

The CDEC model is valuable, since it is derived from actual test data. It also reflects the variation in suppressive capabilities of different weapons more clearly than other models. However, there are two serious limitations to its usefulness. First, the required input of miss distance is not always easily accessible. Second, the equations only apply to the weapons and conditions set forth in the CDEC experiments (e.g., the only target posture considered was personnel in foxholes with head and shoulders exposed).

2.4 The ASARS Model.

The ASARS model (Reference 3) is unique in that it considers seven suppression states, each of which is interpreted as a certain percent degradation in firing, observation, and movement. The suppression states are numbered 0 through 6 (0 = no suppression and 6 = total neutralization), and the percentage degradations in performance for each state were derived from the results of a questionnaire administered to infantry organizations. The results are as follows:

Suppression State	Percent Degradation		
	Observe	Move	Fire
0	0	0	0
1	18	18	18
2	31	100	31
3	54	100	54
4	70	100	100
5	92	100	100
6	100	100	100

To determine the suppression state for an individual receiving fire, a binomial distribution $(6,\theta)$ is assumed so that the probability of an individual being in suppressed state λ is

$$P(X=\lambda) = \frac{6!}{\lambda!(6-\lambda)!}(1-\theta)^{6-\lambda}\theta^{\lambda}$$ where θ is a function of the expected fraction of

casualties ($\bar{f}$) associated with the firing event. By using data from a perceived dangerousness experiment conducted by Litton (Reference 4), the following relationship was obtained:

$$\theta = 1.13 + 0.0527 \ln(\bar{f}) \qquad 0 < \bar{f} < .085\ ^{*}$$

Thus, the probability of attaining a given suppression level is calculated as a function of $\bar{f}$ and interpreted directly as a reduction in efficiency of acquisition, movement, and firing. For duration of suppression, it is assumed that a unit suppressed to level A will drop to level A/2 after the next time interval in the ASARS Battle Model.

The ASARS model shares the favorable feature of the Litton model that only $\bar{f}$ is required as input. However, it appears to be supported by experimental data more than the Litton model. (Responses to questionnaires have confirmed the choice of a binomial distribution for suppression states), and it provides for varying degradations of the three functions of combat considered within each suppression state.

Of course, as was mentioned previously, any model which relies on $\bar{f}$ might fail to reflect properly the variance in suppressive capabilities of different weapons. Another problem with the ASARS model is in the development of the relationship between $\bar{f}$ and θ. The data from which this relationship was derived shows a very poor correlation.

Overall, the development of the ASARS model appears to be mathematically sound, and it has potential value for predicting direct fire suppression of infantry. For this reason, work has been done to correct the problems stated in the preceding paragraph. The results are described in the next section.

2.5 Revisions to the ASARS Model.

An effort has been made to improve upon the relationship derived by ASARS to predict θ from $\bar{f}$. Using the passive squad target model developed at AMSAA, and choosing a medium range of 300 meters and an engagement period of 20 seconds, values of $\bar{f}$ were generated for the weapons and rates of fire employed in the Litton perceived dangerousness experiment. These were paired with values of θ from the Litton experiment. (In the experiment, values of θ were obtained for several miss distances. These have been averaged to yield one θ value for each weapon and each rate of fire). A least squares linear regression was performed on these data. The result was a much improved relationship as given in the following equation:

$$\theta' = 1.638 + .2634 \ln(\bar{f}) \qquad 0 < \bar{f} < .074\ ^{*}$$

The correlation coefficient for this regression is 0.78, which is not as high as desired, but significantly higher than the original relationship

* For extremely small values of $\bar{f}$ (which would permit θ/θ' to be negative) θ/θ' is defined to be 0. Similarly, if $\bar{f} > .085/.074$, θ/θ' is defined to be 1.

derived by ASARS ($r = .6$). As more data are obtained, a more accurate relationship should be attainable.

There is also a need for the model to reflect the variance in suppressive capabilities of weapons. This has been done by making use of the CDEC suppression data. By comparing the suppression values predicted by the CDEC model for the direct fire weapons involved in the CDEC experiments, adjustment factors were obtained, which indicate roughly the ratio of probability of suppression for the given weapon firing with a certain attrition rate ($\hat{f}$) to probability of suppression for the 7.62mm machinegun firing with the same attrition rate. The factors obtained are as follows:

Weapon	Factor
5.56mm Rifle	0.85
7.62mm Machinegun	1.00
.50 Caliber Machinegun	1.60
20mm Cannon	1.10
40mm Grenade Launcher	0.78

It should be noted that these factors are not intended to represent directly the relative suppressiveness of the weapons, because they are obtained for similar values of $\hat{f}$. (For example, the factor of 0.78 for the 40mm grenade launcher does not imply that it is less suppressive than the 7.62mm machinegun, because the 40mm grenade launcher generally produces higher values of $\hat{f}$ than the 7.62mm gun. However, in firing events for which $\hat{f}$ values are similar, the machinegun should be more suppressive). This factor is multiplied by θ' to produce θ, which is used in the ASARS model as previously described. (For weapons not included in the CDEC experiments, it must be assumed at present that $\theta' = \theta$). This method of calculating θ should strengthen the ASARS model, although it is recognized that there is a need to improve the method further. Perhaps, as more data are received, it would be possible to predict θ as a function of some other variable or variables.

2.6 The DYNTACS Model.

In the DYNTACS model (Reference 5) suppression is dependent upon the distance from a target to the impact of a round. For direct fire, the round must hit or land directly in front of the target to produce suppression. For indirect fire, an elliptical suppressive region centered at the center of impact of a volley is input for each weapon, round and target combinations. Any unit which lies in the ellipse is suppressed. Suppressed units are unable to fire or acquire targets, but movement is not degraded. The duration of suppression is also provided as an input to the model.

This model achieves the desirable quality of simplicity at the cost of a complicated set of inputs which are difficult to obtain and may vary widely from one study to another. The DYNTACS model is limited to use in Monte Carlo programs which model impacts of individual volleys.

2.7 The Naval Weapons Center Model.

The model developed by the Naval Weapons Center (Reference 6) is similar to the DYNTACS model in that targets are suppressed if they are within the suppression region surrounding the impact of a round. Here the suppression region is defined by $P_{(K)}$ contours which we specified by input. Also, the Naval Weapons Center model is much more sophisticated. A target can be in one of three suppressed states, depending upon the proximity of the round impact. If the target is inside the .001 P_K contour (a region around the center of impact of a round inside which the probability of kill is greater than or equal to .001), it is placed in the first suppressed state. Inside the .01 P_K contour targets are suppressed to the second state, and inside the .1 P_K contour suppression state three is reached. The only difference in the three states is the recovery time. In the first state (S_1), a target will become unsuppressed (provided no new fire is received) after the next battle interval (5 to 10 seconds), whereas targets in state two (S_2) remain suppressed for two periods, and in state three suppression is maintained for three battle periods. A Markov chain is used to determine the suppressed state of a target in successive time intervals with units moving up or down in suppressed states, depending on the proximity and lethality of future rounds.

Another unique feature of the Naval Weapons Center model is that suppressed targets are less vulnerable and, therefore, have lower P_K's than when unsuppressed. Most of the models considered in this report do not reduce the vulnerability of a suppressed target.

The model makes no effort to predict effects of suppression. Instead, the fraction of time a target is suppressed or incapacitated is computed as a measure of effectiveness of a mission. The choice of threshold P_K values of .001, .01, and .1 is crucial to the Naval Weapons Center model. Although a limited effort has been made to justify the values chosen, they may still be open to question.

2.8 The CARMONETTE Model.

Suppression in CARMONETTE (Reference 3) is very similar to DYNTACS. A target is suppressed when a certain amount of fire is received within a designated time interval (commonly 60 seconds) in a region surrounding the target. The amount of fire required to produce suppression is measured in neutralization weights per grid square

containing the target. These are provided as input for each target as well as an impact area of suppression and a neutralization weight per round for each weapon.

Two levels of suppression may be achieved, depending on the neutralization weights per grid square delivered. A target may be "pinned down", resulting in an inability to move and reduced acquisition and firing effectiveness. The target may be "partially neutralized", in which case weapon accuracy is 50% degraded, aiming time is doubled, acquisition is reduced 25% and movement is slowed.

As an example, in one study a neutralization weight per round of 15 was input together with an impact area of 300 X 300 meters for the 155mm Howitzer. For dismounted troops, the values of 200 and 143 neutralization weights per grid square were input as threshold values for the units to be "pinned down" and "partially neutralized", respectively. Hence, 10 rounds of 155mm projectiles delivered per grid square per minute will partially neutralize troops within 150 meters of the center of impact, and 14 rounds per minute will keep them pinned down.

CARMONETTE shares with the Naval Weapons Center model a reduced vulnerability to fire for suppressed units. In CARMONETTE a suppressed infantry unit is 50% less exposed.

The inputs required for CARMONETTE are numerous, and the method of selecting values of those inputs appears to be rather arbitrary. Inputs which are readily obtainable from available data would be more favorable.

2.9 The JIFFY Model.

The JIFFY model (Reference 5) computes suppression from the firepower score of each weapon. The firepower score is adjusted according to type of engagement, and ratios of attacker to defender firepower are computed for maneuver weapons and for support weapons. A table of suppression probabilities associated with firepower ratios is input, and the suppression value for the appropriate firepower ratio is extracted. The probability of suppression is directly interpreted as a fractional reduction in enemy weapons killed.

The JIFFY model, like CARMONETTE and DYNTACS, relies heavily on input. The basis for the table of suppression values used in JIFFY is unclear. According to Willis (Reference 4), the source seems to be judgmental.

2.10 Vector Research Proposal.

Vector Research introduced in April 1975 (Reference 7) a suppression model for possible implementation into the TRASANA AIDM

(AMSAA Improved Differential Model). The Vector proposal includes a lenghty discussion of numerous equations for the effects of suppression, with units being transferred from suppressed to unsuppressed groups and vice versa, so that acquisition, vulnerability, etc., may be computed separately from units in suppressed groups and units in unsuppressed groups. However, the entire model is based upon computing a single round probability of suppression and accumulating that for all rounds and all weapons firing at a given target. The single round probability of suppression (S) is calculated as a function of probability of a non-lethal hit (NLH) and probability of a near miss (NM). The following formula is used:

$$P(S) = P(S/NLH) \times P(NLH) + P(S/NM) \times P(NM)$$

P(NLH) and P(NM) are computed in the program, but P(S/NLH) and P(S/NM) must be provided as input. Furthermore, a suppressive area must be defined, before P(NM) can be calculated. Thus, a user would need essentially to know the probability of suppression for each weapon and target combination before using the suppression model. The value of the model is, therefore, questionable.

2.11 Proposal by Horrigan Analytics.

Horrigan Analytics has proposed a model for expected duration of suppressive effect and detection time while under suppressive fire. (Information was obtained from an unpublished report by Timothy J. Horrigan of Horrigan Analytics titled, "Detection in the Presence of Nonuniform, Mixed Suppressive Fires). A formula for duration of suppression as a function of constant single-round duration of suppression and the intensity of fire is given, and a corresponding formula for expected detection time is developed, Then these formulas are revised to allow for the single round duration of suppression to be considered as a function of miss distance, and to consider any mixture of projectile types fired. Finally, the model is generalized to consider fractional suppression.

This model is only concerned with duration of suppression and detection time. No effort is made to predict the probability of becoming suppressed or the effect of suppression on movement or firing efficiency.

3. COMPARISONS OF EXISTING MODELS

Comparisons have been made for five of the models discussed in the previous section. The Litton, CDEC and ASARS direct fire models are compared, and the Litton, RARDE, CDEC and DYNTACS models for indirect fire and compared. The DYNTACS comparison is limited to the 155mm Howitzer, since that is the only weapon for which data were available. The other models are excluded due to a lack of data available or an inability to establish a basis for comparison.

Clearly, it is impossible to obtain pure, straightforward comparisons of the models, since each is based on different assumptions about the nature of suppression. It should be noted, then, that certain assumptions must be made in order to put the models on common ground. These assumptions are described for each comparison constructed, and any evaluation of the comparisons should be made in consideration of those assumptions.

3.1 Direct Fire.

The passive squad target model developed at AMSAA's Ground Warfare Division was used to generate expected fraction of casualties ($\bar{f}$) and radial miss distances for 20 second engagements against a squad of eight men. The squad is randomly located in a 50 meter wide area and in foxholes with head and shoulders exposed. The firing technique was to sweep across the target area firing single bursts at pre-determined aim points. A matrix of weapons, ranges, number of aim points and rounds per burst employed is given below:

Weapon	Range	Aim Points	Rounds/Burst
5.56mm rifle	100	10	3
	300	9	3
	500	9	3
7.62 mm machinegun	200	10	6
	400	9	6
	600	8	6
	900	8	6
	1200	7	6
20mm cannon	400	9	5
	800	8	5
	1200	7	5
	1600	6	5
.50 cal machinegun	400	9	6
	800	8	6
	1600	6	6
40mm grenade launcher	400	9	5
	800	8	5
	1200	7	5
	1600	6	5

The value of $\bar{f}$ was used to compute suppression by the Litton model (with $\rho = 1.0$) and the ASARS model (using the revised relationship between $\bar{f}$ and θ, as described in Section 2.5). Since probability of suppression is not computed in ASARS, the values given are the calculated fractional reductions in efficiency of observation, movement

and firing. The average radial miss distance for the rounds of each burst (in the vertical plane of the target) from each man was used to obtain a probability of suppression by the CDEC model, which was accumulated for all bursts fired. Thus, for K bursts fired, if S_i is the probability of suppression for burst i, then the accumulated probability of suppression is:

$$P(S) = 1 - \prod_{i=1}^{k} [1-P(S_i)]$$

The complete results are shown in Table 1, with sample graphs of suppression as a function of range for three of the weapons given in Figures 1, 2 and 3.

3.2 Indirect Fire.

A comparison of the Litton, CDEC, and RARDE models for indirect fire suppression was made, using delivery accuracies and effectiveness data from the Joint Munitions Effectiveness Manual (JMEM). Weapons considered were the 81mm mortar, 105mm Howitzer and 155mm Howitzer, firing HE projectiles with both air and ground bursts. Two delivery techniques were chosen. An effort was made to use tactically realistic rates of fire, ranges, and battery formations. The target was assumed to be prone personnel in open terrain.

Litton suppression values were calculated directly from JMEM casualty data for the target radii selected. To facilitate computation of RARDE and CDEC values, the target area was divided into 100 meter squares, with one individual assumed to be located in the center of each square. Delivery accuracies were used to calculate the probability of a round landing in each square. Thus, an intensity of fire in each square was obtained (assuming a certain time period for the firing event) and used in the RARDE model. An average miss distance from each individual in the target area was estimated for rounds landing in any given square, so that probability of suppression by the CDEC model could be calculated and accumulated over all squares for each weapon in the battery.

The complete results of these computations are shown in Table 2, with sample graphs in Figures 4, 5, 6 and 7. These comparisons should only be considered as rough estimates due to averaging required in computation of CDEC and RARDE values.

A similar comparison was attempted for DYNTACS, LITTON and RARDE. However, in DYNTACS suppression probabilities are not computed. Instead, an elliptical suppressive region is input, and targets lying within it are suppressed. Input values of 170 for lateral radius and 70 for forward radius were obtained for the suppressive region for a 155mm Howitzer firing an HE projectile, ground burst. A probability of suppression was generated by taking the ratio of individuals in the target region (located at the center of each square) who are in the

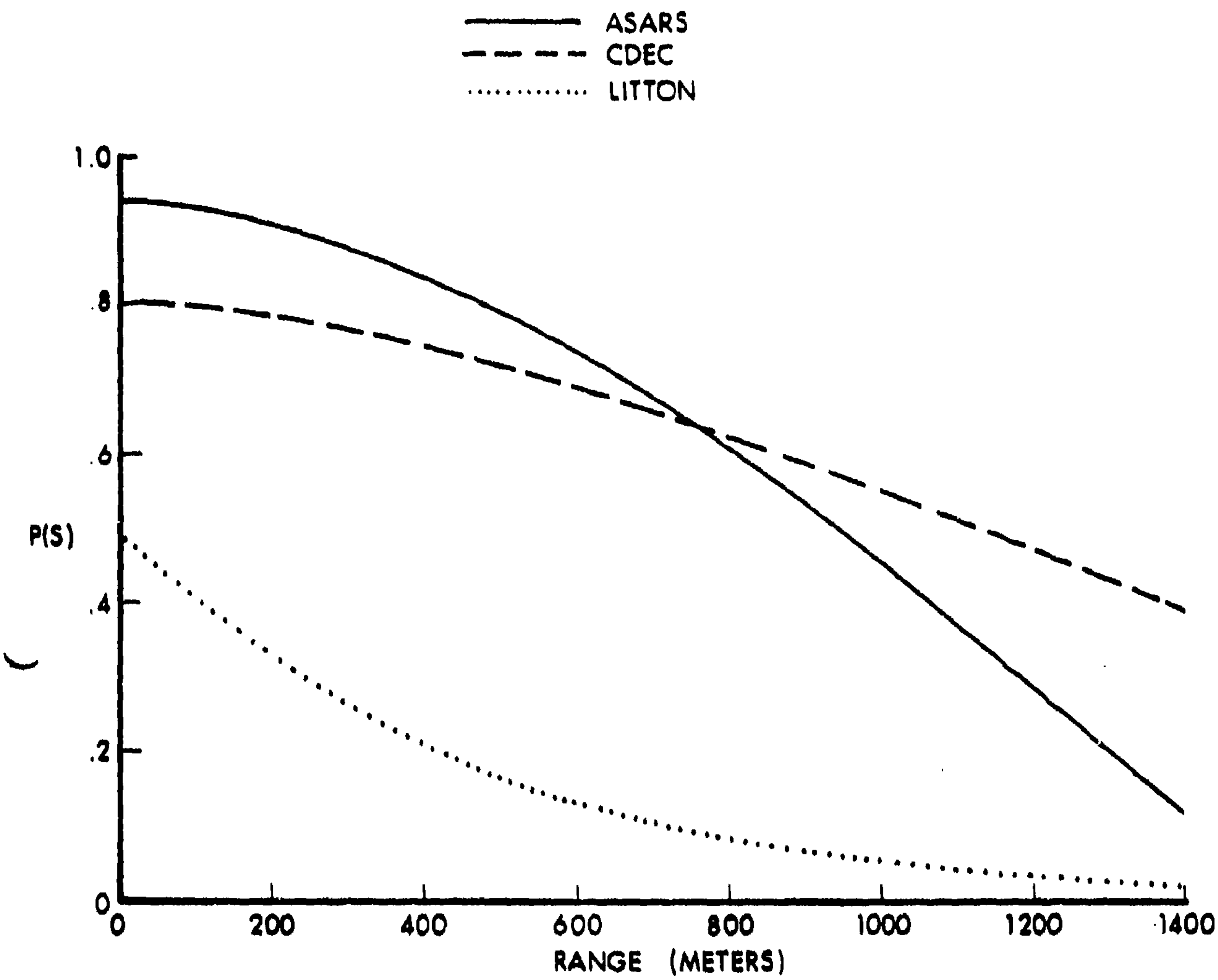


Figure 1. Direct Fire Suppression - 7.62MM Machine Gun.

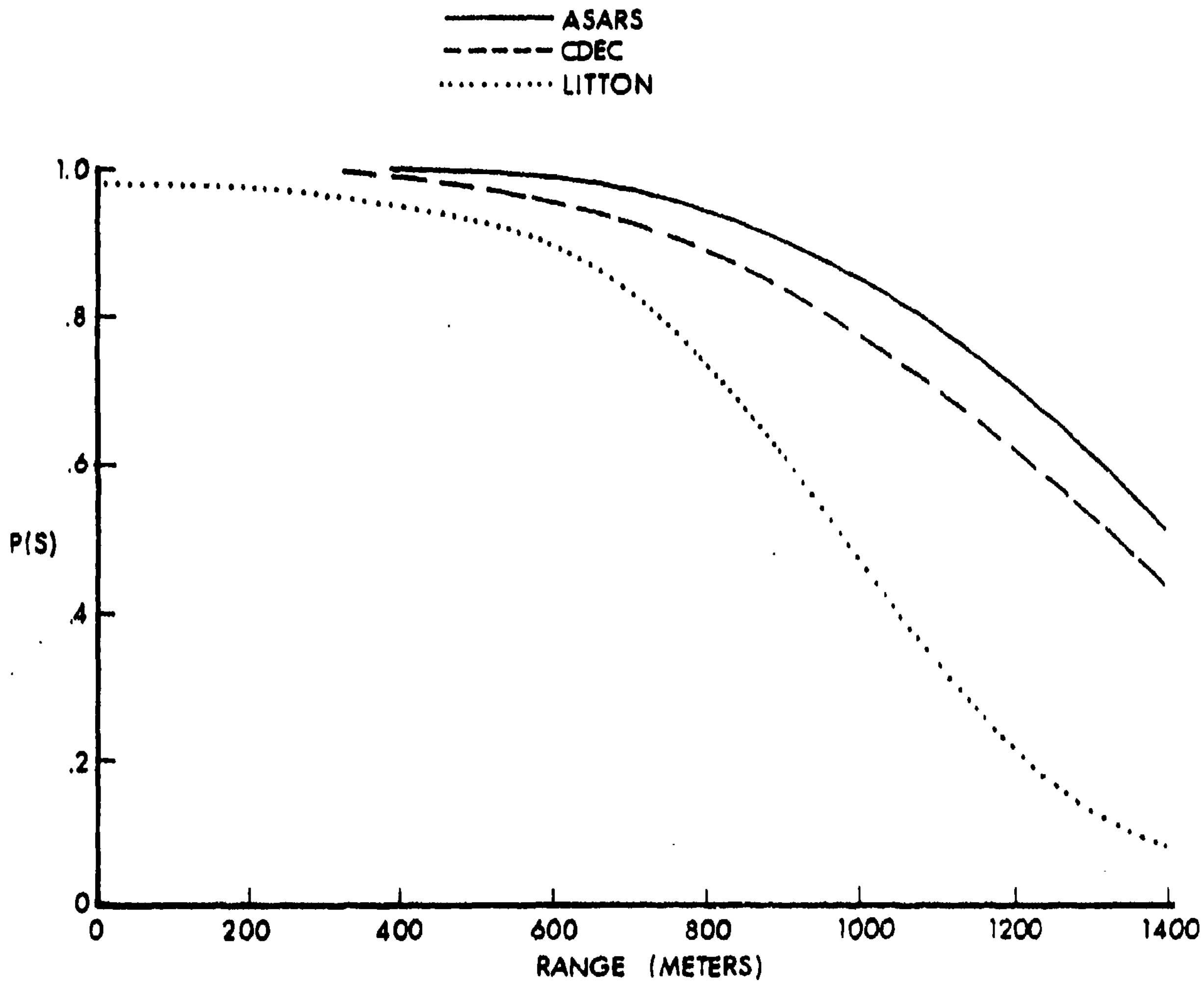


Figure 2. Direct Fire Suppression - 40MM Grenade Launcher.

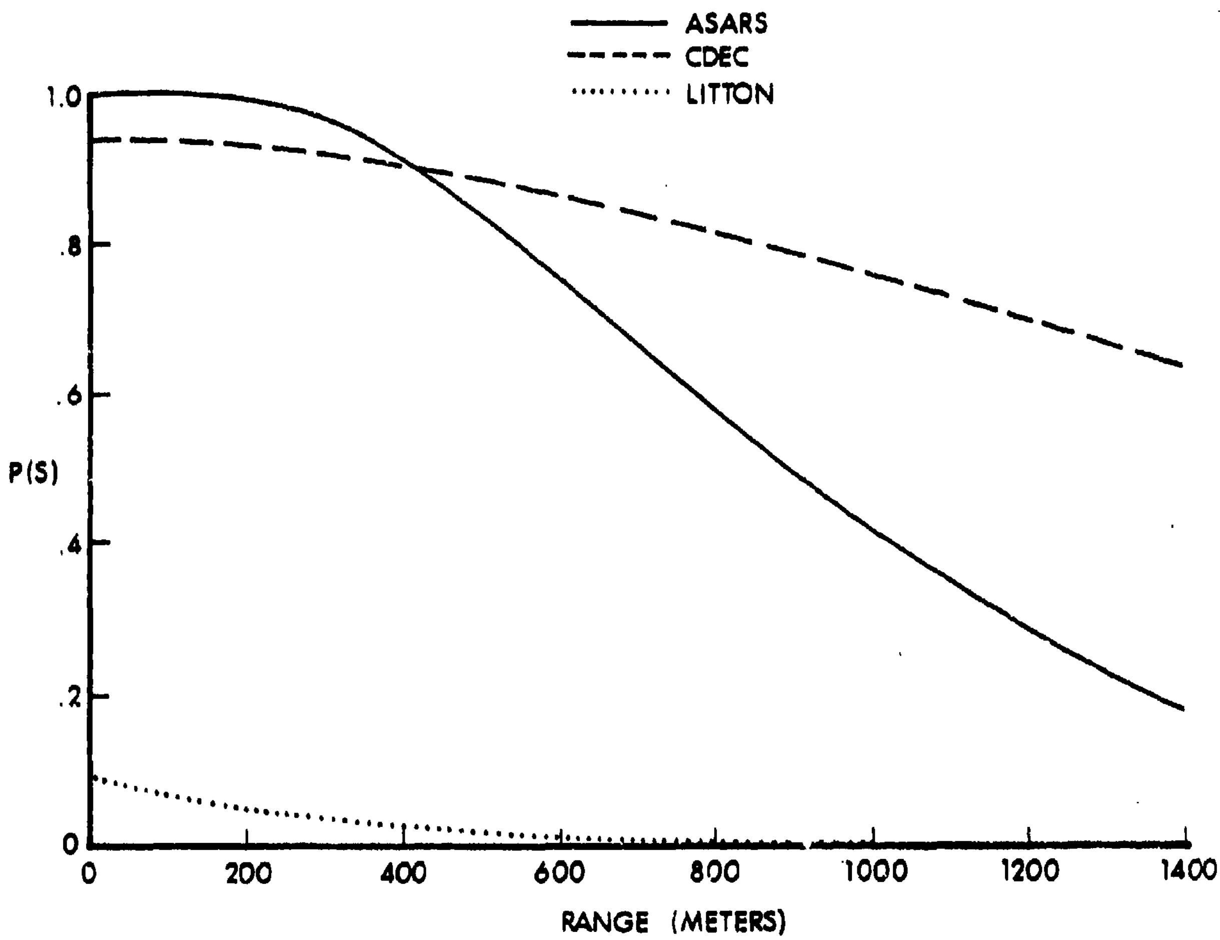


Figure 3. Direct Fire Suppression - .50 Caliber Machine Gun.

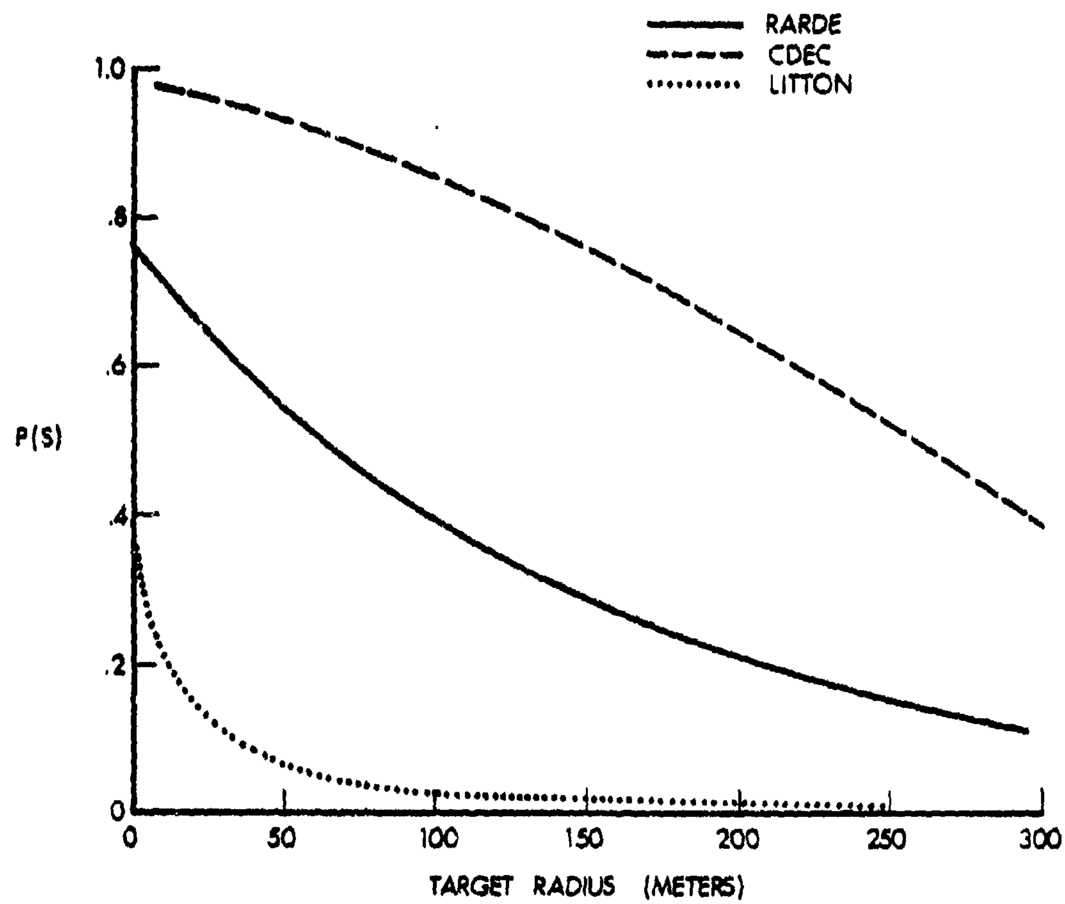


Figure 4. Indirect Fire Suppression - 105MM Howitzer
1 Volley, Air Burst, Met + Ve Technique.

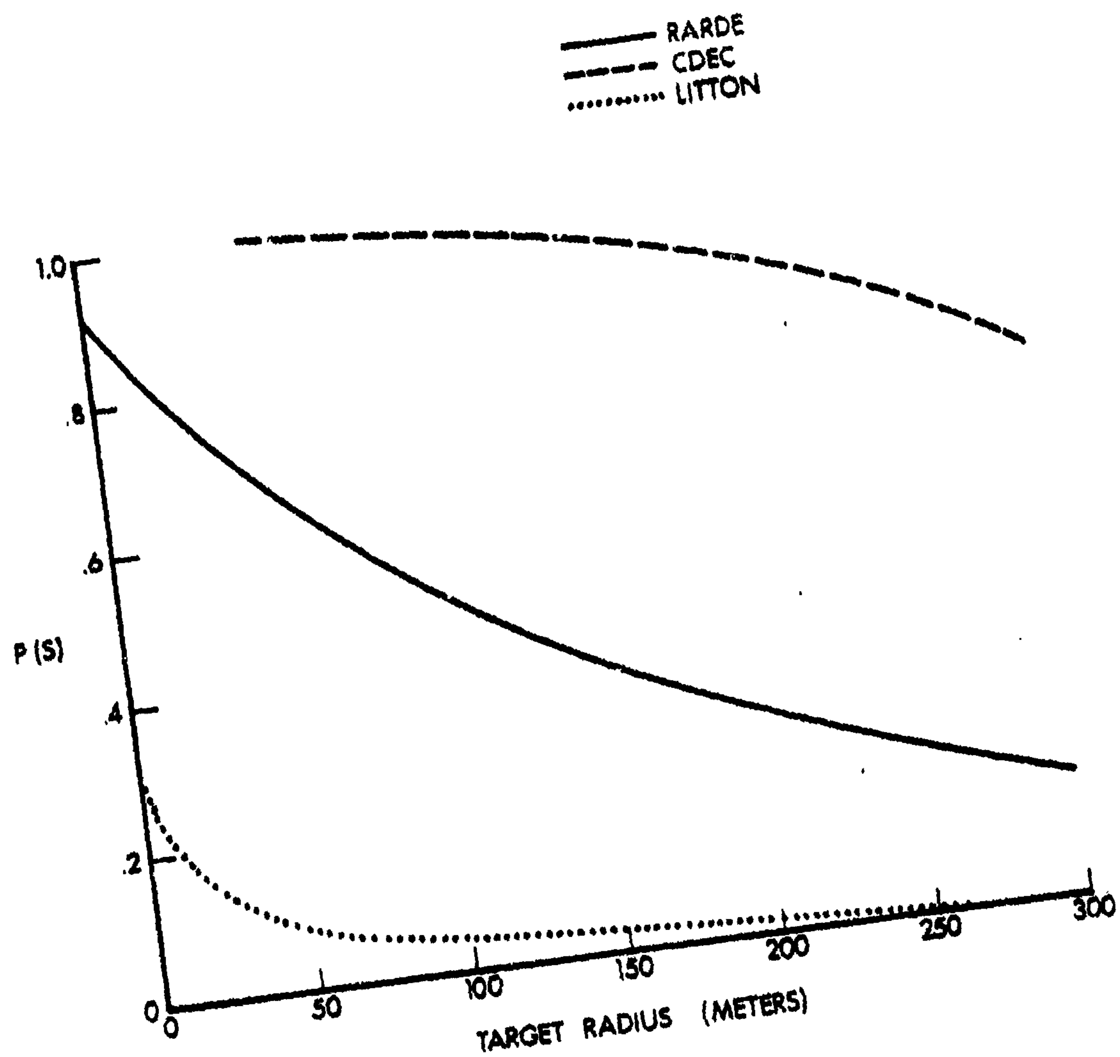


Figure 5. Indirect Fire Suppression - 105MM Howitzer Ground Burst, 3 Volleys, Met + Ve Technique.

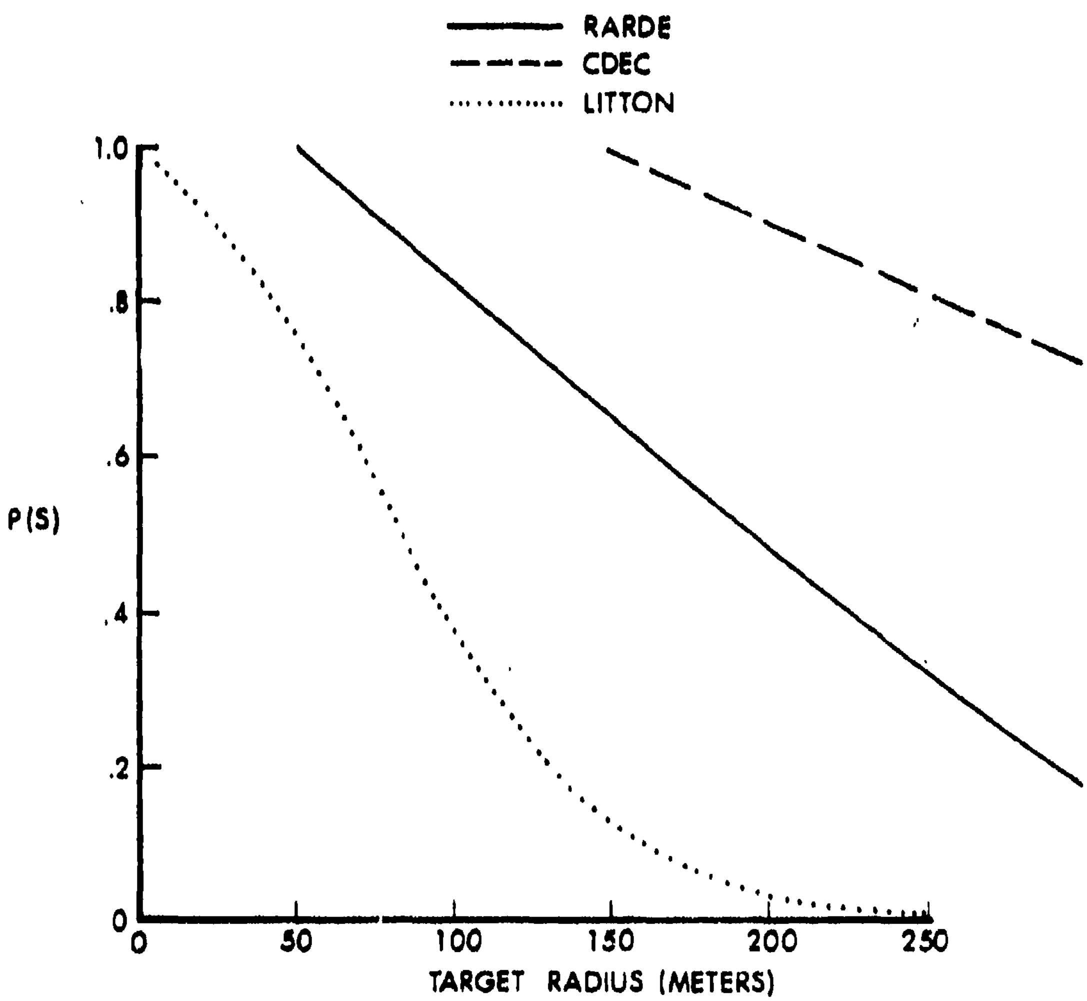


Figure 6. Indirect Fire Suppression – 105MM Howitzer Air Burst, 1 Volley, Observer Adjusted.

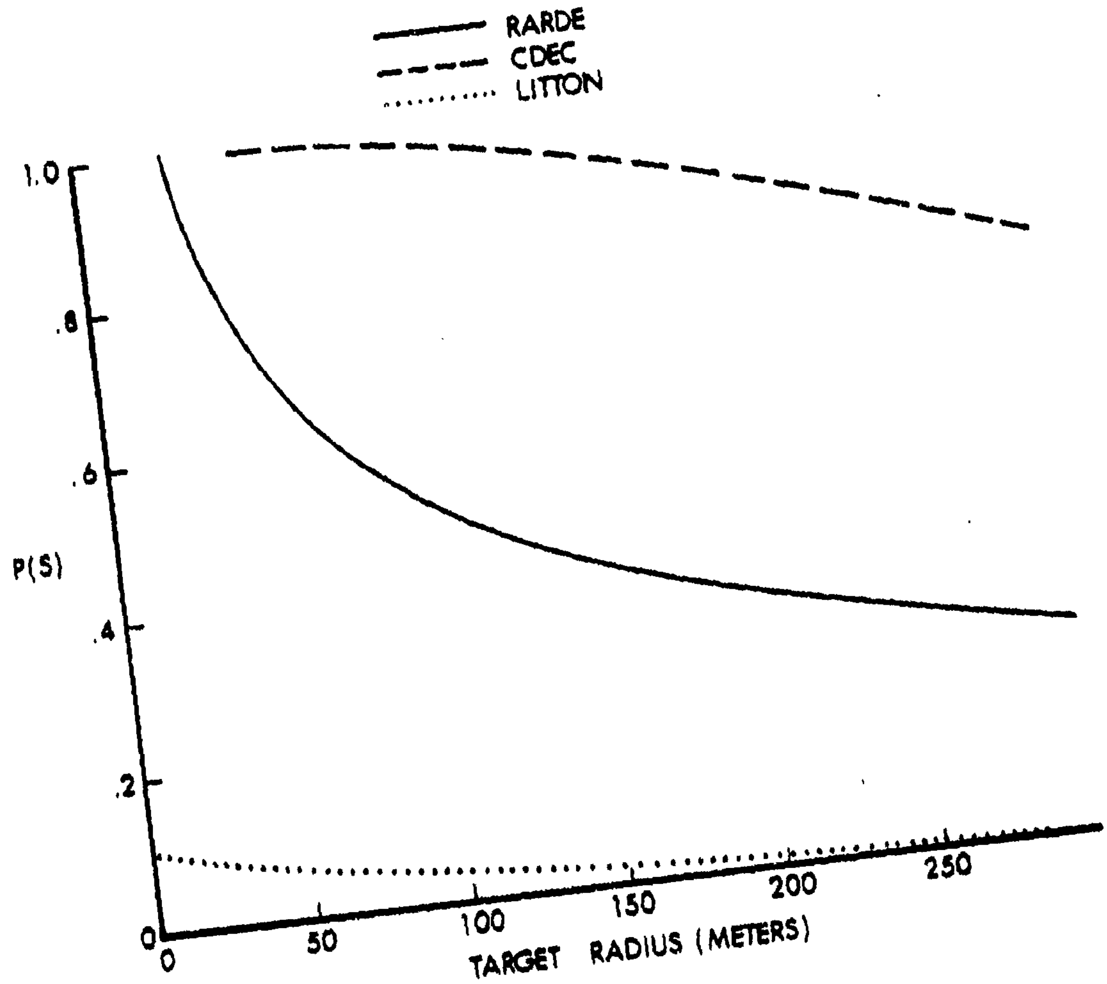


Figure 7. Indirect Fire Suppression - 105MM Howitzer Ground Burst, 3 Volleys, Observer Adjusted.

suppressive region to the total number of individuals in the target area. An illustration for a 300 X 300 meter target area is shown in Figure 8. It may be observed that three of the nine individuals in the target area lie within the suppressive ellipse. Thus, the probability of suppression is calculated to be .33. (It may be more accurately termed the fraction of the target suppressed.) A table of the suppression values is also given in Figure 8.

It should be emphasized that the values obtained in these comparisons can not be taken as completely accurate. Because of the extreme difference in the nature of the models compared, assumptions, as described above, were required, which could lead to some computational inaccuracies. However, these comparisons should provide some insight as to the relation of the models to one another.

4. PROPOSAL FOR AN INTERIM SUPPRESSION MODEL

From examining the models and the nature of suppression, it appears that suppression should be divided into direct fire and indirect fire suppression, each of which should be subdivided into suppression of personnel and suppression of vehicles. Any model for suppression should consider all these areas separately. The proposals for modeling indirect fire and direct fire suppression of personnel and vehicles are given in the next two sections.

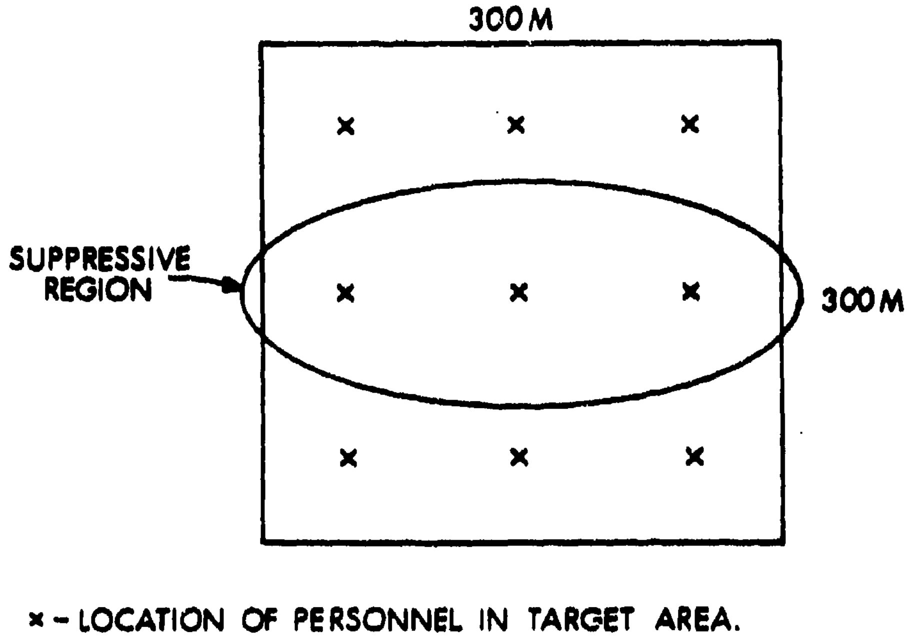
4.1 Direct Fire.

For direct fire against personnel, the ASARS model with the revision, and inclusion of the CDEC data, as given in Section 2.5 is proposed. The validity of the binomial distribution has been confirmed by empirical data, and it allows for varied degradation in performance of the functions of combat without relying on arbitrary inputs or extremely complicated formulas. It is based directly on empirical data, an area in which most other suppression models are lacking. Also, the calculation of θ could be adjusted as more data are received without affecting the development of the model.

For direct fire against vehicle crews it seems reasonable to adapt the criterion that a direct hit can cause suppression. Therefore, it is proposed that the probability of suppression be equated to the probability of a hit for vehicles. Acquisition and movement should be degraded for suppressed vehicles.

4.2 Indirect Fire

The RARDE model is recommended for indirect fire suppression. It considers personnel and vehicles separately, although the methodology is similar. The RARDE model is shown in the comparison to predict values between the values of Litton and CDEC which in itself is no justification. However, the modeling of indirect fire suppression as a function of intensity of fire is intuitively



Delivery Technique	Target Radius	Probability of Suppression One Volley (Six Rounds) Litton	RARDE	DYNTACS
Observer	50m	.75	1.0	1.0
Adjusted	150m	.27	.55	.33

Range: 10,000m
Time: 30 Seconds
Battery of 6 in Lazy W Formation
Open terrain; ground burst
Target: Prone personnel

Figure 8. Indirect Fire: DYNTACS Comparison 155MM Howitzer.

appealing, and by using lethal areas to define intensity of fire, the model acquires a favorable responsiveness to variations in weapon types, target posture, terrain and other variables. Lethal areas are available for most weapons and conditions, and the intensity of fire is not difficult to calculate.

It is believed that the use of the model proposed here would significantly improve the quality of the representation of suppression in AMSWAG, and other combat simulations. More precise models may be developed as the nature of suppression becomes better understood.

5. RECOMMENDATIONS FOR FUTURE EFFORTS

Any improvements in the modeling of suppression depend upon the collection and analysis of meaningful suppression data. Objective experimental data are desirable, but not easily obtained. Delphi studies can be very valuable, provided the sample is large and not biased. Two specific recommendations for data collection are made here:

a. A field experiment similar to the one conducted by Litton on perceived dangerousness should be conducted, using a greater variety of weapons and a larger number of trials, in order to validate or improve upon the relationship developed between f and θ in the ASARS model. Also, the participants should be given descriptions of the suppression states defined in the ASARS model. They could then be asked to associate the fire received in each trial with one of the suppression levels rather than with the vague notion of dangerousness.

b. Delphi studies should be conducted to validate (or invalidate) the percentage degradations of observation, movement and firing in the suppression states of ASARS, and the choices of threshold intensities and associated movement and acquisition reductions in the RARDE indirect fire model. A sufficient number of responses from a cross-section of individuals should confirm the values suggested or strongly establish new values. It is believed that the data from these efforts will greatly enhance the modeling of suppression and make progress toward putting it on a solid basis of empirical data.

TABLE 1. DIRECT FIRE SUPPRESSION

Squad of 8 Men
20-Second Engagements, Using
Passive Squad Target Model

					Suppression				
Weapon	Range	$\bar{f}$	θ'	θ	Litton	CDEC	Obs*	Move*	Firing*
5.56mm	100m	.023	.694	.590	.19	.59	.62	.96	.72
Rifle	300	.018	.629	.535	.12	.62	.56	.91	.61
	500	.006	.340	.289	.01	.60	.29	.60	.31
	200m	.039	.833	.833	.28	.76	.87	1.0	.96
7.62mm	400	.037	.820	.820	.29	.75	.86	1.0	.96
Machinegun	600	.020	.658	.658	.13	.71	.71	.98	.83
	900	.014	.564	.564	.07	.64	.60	.95	.70
	1200	.005	.292	.292	.01	.46	.29	.61	.31
	400m	.013	.544	.870	.02	.88	.91	1.0	.98
.50 cal	800	.006	.340	.544	.01	.82	.58	.94	.67
Machinegun	1600	.001	.000	.000	.01	.58	.00	.00	.00
	400m	.166	1.0	1.0	.79	.98	1.0	1.0	1.0
20mm	800	.121	1.0	1.0	.64	.98	1.0	1.0	1.0
Cannon	1200	.041	.847	.931	.26	.89	.96	1.0	.99
	1600	.023	.694	.763	.16	.82	.80	.99	.91
	400m	.312	1.0	1.0	.95	.99	1.0	1.0	1.0
40mm	800	.147	1.0	.92	.74	.93	.95	1.0	.99
Grenade	1200	.021	.773	.603	.21	.58	.65	.96	.75
Launcher	1600	.008	.416	.324	.05	.25	.33	.70	.37

*ASARS Degradation For:

1 - Observation
2 - Movement
3 - Firing

TABLE 2. INDIRECT FIRE SUPPRESSION

TARGET: Prone Personnel in Open Terrain

Weapon, Formation, Range, Time of Engagement	Project	Burst Height	Delivery Technique	Target Radius	RARDE	CDEC	Litton	RARDE	CDEC	Litton
105mm Howitzer	M1		Observer	50	1.0	1.0	.11	1.0	1.0	.82
Battery of 6	Comp B	Ground	Adjusted	150	.28	.96	.01	.71	1.0	.11
Lazy W Formation	Loaded		MET+VE	50	.01	.90	.01	.67	1.0	.03
Range: 9000m		1	TLE=75	150	.00	.71	.01	.39	.98	.03
			Observer	50	1.0	1.0	.75	1.0	1.0	.97
Time: 30 Sec		15 ft	Adjusted	150	.65	1.0	.11	.97	1.0	.75
			MET+VE	50	.54	.93	.03	1.0	1.0	.47
		2	TLE=75	150	.29	.76	.01	1.0	1.0	.27
8-In Howitzer			Observer	50	.13	1.0	.01	1.0	1.0	.27
Battery of 4	M106	Ground	Adjusted	150	.04	1.0	.01	.52	1.0	.11
			MET+VE	50	.00	1.0	.01	.15	1.0	.03
Stagger	TNT		TLE=75	150	.90	.98	.01	.06	1.0	.03
Formation	Filled		Observer	50	.81	1.0	.11	1.0	1.0	.87
		15 ft	Adjusted	150	.39	1.0	.03	.94	1.0	.63
Range: 10,000m			MET+VE	50	.08	1.0	.03	.87	1.0	.47
Time: 1 Min			TLE=75	150	.02	1.0	.01	.63	1.0	.27
81mm Mortar	M374	Ground	Observer	50	1.0	.95	.27	1.0	1.0	.90
Platoon of 3			Adjusted	100	.57	.75	.03	.75	.97	.63
Range: 3000m		7 ft	Observer	50	1.0	**	.63	1.0	**	.97
*Time: 30 Sec			Adjusted	100	.67	**	.27	.83	**	.90
105mm Howitzer		1 Ground	MET+VE	250	.00	.52	.00	.23	.84	.01
		2 Air	MET+VE	250	.15	.60	.01	.80	.92	.03

*The 81mm mortar normally fires at a much higher rate, but this rate chosen to provide a more meaningful comparison.

**No data were obtained by CDEC.

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APPENDIX E

Suppressive Effects of Artillery Fire

By

F.W. Niedenfuhr (MITRE Corporation for DARCOM)

SUPPRESSIVE EFFECTS
OF ARTILLERY FIRE[1]

F. W. NIEDENFUHR

The MITRE Corporation
Washington C^3 Operations
McLean, Virginia

For presentation at the Fire Suppression Symposium
U.S. Army Field Artillery School, Ft. Sill, Oklahoma
24-25 July 1979

[1]Results reported here were obtained in the course of a study entitled Counterfire Campaign Analysis, conducted by The MITRE Corporation under sponsorship of the Directorate of Battlefield Systems Integration, U. S. Army Materiel Development and Readiness Command, Contract No. F 19628-79-C0001

ABSTRACT

Some definitions of suppression are suggested and formulas are proposed for the suppression and attrition of cannon artillery batteries. These show the dependence of suppressive effects on both technological and behavioral parameters. Results from combat modeling and simulation are introduced to illuminate the impact of suppression by counterfire on the central battle. Scenario dependent effects are discussed.

1.0 INTRODUCTION

The analysis of suppressive effects has proved to be neither simple nor definitive, as is attested by the proliferation of measures and models of suppression. It is apparent that the problem is not nearly as well in hand as is, say, the problem of calculating weapons effects. Indeed, many more insights need to be developed before a definitive view of suppression can be attained. The writer hopes that this symposium will prove to be a positive step in this direction; it is by no means obvious, however, that the final answers will emerge here or even in the near future. Experimentation and innovation are to be encouraged.

In this paper we use the term *suppression* in the sense of a temporary or transient reduction of an opponent's ability to be productive. Permanent reductions in the opponent's productivity are said to be due to *attrition*, and we take the point of view that it is the fear of attrition that causes suppression. We postulate, however, not an irrational fear of attrition, but an enlightened, experienced, or battle-wise fear. Thus, suppression is taken to be a loss of productivity due to evasive action to avoid attrition.

It is not possible to say with certainty exactly how human beings will behave under any given circumstances. It is possible, however, to investigate the consequences - in terms of attrition and productivity - of various alternative behaviors. Having done this, one can identify the behavioral path which is most advantageous. In combat modeling, we select that behavioral path which leads to minimum attrition or maximum combat productivity, according to the urgency of the combat situation. Thus, while it is not true that humans *will* select an optimal behavior path, we believe that in the

the long run most people will learn to avoid the aversive consequences of non-optimal behavior.

It is better to be lucky than wise. Some weapon crews will be lucky, living and maintaining productivity despite a hail of lethal incoming fire. Being lucky, they never learn; they never *need* to learn. Analysis cannot say much about such people, except that there will be few of them. Analysis, however, can describe those fellows who do not live a charmed life, and it is to them that we devote our attention here. We idealize their options by postulating that, at any given time, they exist in one of two mutually exclusive states: either a state in which they are productive but vulnerable (i.e., have a given probability, P_1, of being killed by an incoming volley) or a state in which they cannot be productive but have a lesser probability, P_2, of being killed when a volley arrives. Qualitatively, one says that units are suppressed to the extent that their integrated productivity is reduced because they have elected - or been forced - to remain in the second state for at least part of the time.

These ideas would seem to be applicable to a variety of combat situations; all that is necessary is to be able to define the states, their associated kill probabilities, and the intended product of the suppressed units. Maneuvering units may have their product measured in terms of kilometers of advance; command centers have a product which might be measured in terms of message units; and artillery units have volleys fired as a natural product to measure. The states and associated kill probabilities are obviously also different for different types of units. Thus, the analysis of suppressive effects is necessarily scenario dependent because different victim units have different productivities and can take different types of evasive

action. Suppressing tactics can also vary through choices of weapon, munition, frequency, and duration of suppressive fire.

In the body of this paper, we specialize to consider suppression of cannon artillery units by other cannon artillery units. Even here it is necessary to divide the work into two parts, according to whether the victim weapons are towed pieces or armored self-propelled. The natural units to consider are batteries, because they consist of elements which have a high degree of behavioral coherance due to the command structure and because each of these elements is subjected to approximately the same degree of risk at the same time.

2.0 FACTORS CONTROLLED BY THE SUPPRESSOR

The suppressor is presumed here to have target location data and to fire standard parallel sheaf volleys which provide reasonably uniform lethal coverage of the victim's battery area. The fractional damage per volley can be computed in a straight forward manner by standard weapon effectiveness techniques, accounting for target location error, weapon precision and bias errors, and the munition lethality. Towed weapon crews can be assumed to get some protection from their weapon itself as well as from its revetment, so their vulnerability is taken as equivalent to that of prone troops. Typical results for single volley fire at midrange by U.S. eight-inch howitzer batteries are given in Table I.

TABLE I

Typical Expected Fractional Damage

Target Element	Munition Type	
	HE	DPICM
SP Weapons	.002	.015
Towed Weapons	.001	.005
Towed Weapon Crews	.030	.200
Troups in Foxholes	.005	.005

Beside the munition and weapon type, the suppressor has a choice of the duration of the action he takes and the number and frequency of suppressing volleys fired over this period. Maximum attrition is generally achieved by massed fire which takes the victim by surprise, but when many single battery volleys are fired in sequence, the first provides a warning and subsequent volleys may act only on troops who have found shelter in convenient foxholes. For an action which takes place over many minutes, there is a question of how best to distribute the suppressing volleys in time. Rapid fire may be wasteful of ammunition for the reason just noted, while slow regular periodic fire gives away too much information; the victim could soon learn to take advantage of regular lapses between volleys. It seems reasonable, therefore, to avoid these problems by randomizing the suppressive volley arrival times so that the victim is encouraged to keep his head down because he cannot predict when the next volley will land. For analytical purposes, it is convenient to represent this type of suppressive fire by a Poisson distribution with a parameter λ which represents the average rate of suppressive volley fire. Then the probability that n suppressive volleys will arrive in a time period of duration T is given by Equation (1).

$$p_n = \frac{(\lambda T)^n}{n!} e^{-\lambda T} \tag{1}$$

In particular, the probability that no suppressive volleys arrive in time T is $e^{-\lambda T}$, and the expected number of volleys in time T is λT.

3.0 FACTORS CONTROLLED BY THE VICTIM

The victim controls his response to incoming fire. For towed artillery batteries engaged in a mission, the victim can opt for one of two states:

- o Continue firing his mission and accept whatever attrition results, or
- o Switch to a non-productive state. There are two ways of doing this:
  - Vacate the position
  - Seek cover in foxholes

Armored self-propelled weapons, in particular Soviet weapons, which can fire with the crew on board, generally will not utilize the second way of becoming non-productive. Although it is safest for the personnel, the weapons themselves are still subject to attrition, and it turns out that vacating the position is the better tactic.

3.1 TOWED UNITS WHICH STAY IN THEIR POSITION

Towed units which do not vacate their firing position can pass back and forth between the protected and productive states. For example, if the average interarrival time of suppressing volleys is long, the suppressed unit could achieve some productivity by coming up out of its foxholes as soon as a volley lands, firing its own weapons for some time, and then returning to foxholes to await the next suppressive volley. We can account for this behavior by defining a duty cycle parameter, α, such that the suppressed unit spends an average time of α/λ in the productive vulnerable state and $(1-\alpha)/\lambda$ in the protected state during each interarrival period.

The value $\alpha=0$ corresponds to always staying in the protected state, while $\alpha=1$ means always staying in the vulnerable state; intermediate values correspond to the mixed strategy.

Victim units which remain in the vulnerable state subjected to kill probability P_1 by each of n incoming volleys have a probability of surviving these volleys given by q_n, where

$$q_n = (1-P_1)^n \tag{2}$$

If these volleys are spread over a time t, and arrive according to the Poisson process suggested above, the victim's probability of survival for this time period is

$$\begin{aligned} q_t &= \sum_{n=o}^{\infty} p_n q_n \\ &= e^{-\lambda t P_1} \end{aligned} \tag{3}$$

Analogously, the probability of survival in the protected state with a kill probability of P_2 is

$$q_t = e^{-\lambda t P_2} \tag{4}$$

so that the average probability of survival during an average length interarrival time is

$$q = \exp - \left[\alpha P_1 + (1-\alpha)P_2\right]. \tag{5}$$

Thus, over n interarrival times, the strength of a unit will be reduced to q^n times its original strength.

As for productivity over this period, we make the simplifying assumption (which is probably valid over long time periods) that the victim's achievable instantaneous rate of fire when performing his own missions is proportional

to his instantaneous unit strength. E.g., it would take twice as long to deliver a number of full volleys when the victim is at half strength as it would at full strength.

Assuming that the victim unit could deliver one full strength volley each t_1 minutes if unopposed and at full strength, it could then deliver Q_n volleys in the (n+1)st interarrival period if it is in the productive state for a fraction, α, of this period:

$$Q_n = \left(q^n/t_1\right)\int_0^{\alpha/\lambda} e^{-\lambda t P_1} dt$$

$$= \frac{q^n}{P_1 t_1 \lambda}\left[1-e^{-\alpha P_1}\right] \quad . \tag{6}$$

It follows that during N periods of length λ^{-1}, the expected total number of volleys that could be delivered by the victim unit is

$$Q = \sum_{n=0}^{N-1} Q_n$$

$$= \frac{1}{P_1 t_1 \lambda}\left[1-e^{-\alpha P_1}\right]\frac{1-q^N}{1-q} \quad , \tag{7}$$

where q is from Equation (5). Further, counting the victim's original strength as unity, the expected residual strength at the end of the N periods is

$$S = q^N \quad . \tag{8}$$

If unsuppressed, the victim could deliver $N/\lambda t_1$ volleys in this time, so that we may define the *suppressed fractional productivity* (SFP) as

$$SFP = Q/(N/\lambda t_1) \tag{9}$$

It is seen that SFP = 0 for $\alpha = 0$ (victim always stays in the protected state), and SFP is given by Equation (10) for $\alpha = 1$ (victim always stays in the vulnerable protected state.)

$$SFP_{\alpha=1} = \frac{1}{NP_1}\left[1-e^{-NP_1}\right] \tag{10}$$

When $\alpha = 0$, the victims remaining fractional strength after N periods is e^{-NP_2}, and when $\alpha = 1$, the remaining fractional strength is e^{-NP_1}.

Thus far we have been concentrating on the case of a towed artillery victim battery, exercising the options of switching between a protected non-productive state (e.g. in foxholes) and a vulnerable productive state. The formulas (8) and (9) make it possible to estimate the attrition and productivity of the victim in this case as a function of his behavioral response to suppressive fire. Figure 1 shows the results of sample calculations for a specific case: N = 10 suppressing volleys fired on a random schedule at an average interval of five minutes, t_1 = .5 minutes, and from Table I, P_1 = .200, P_2 = .005 for DPICM, and P_1 = .030, P_2 = .005 for HE as the suppressive munition. Note how suppression and attrition are interrelated - as the victim acts to preserve his manpower ($\alpha \rightarrow 0$) his productivity is vastly reduced. The relative effectiveness of DPICM and HE is also clearly evident; one can imagine that in an urgent combat situation, the victim might elect to accept the attrition forced on him by manning his weapons continuously when under fire by HE, but it is doubtful if he could adopt this tactic under suppresion by DPICM.

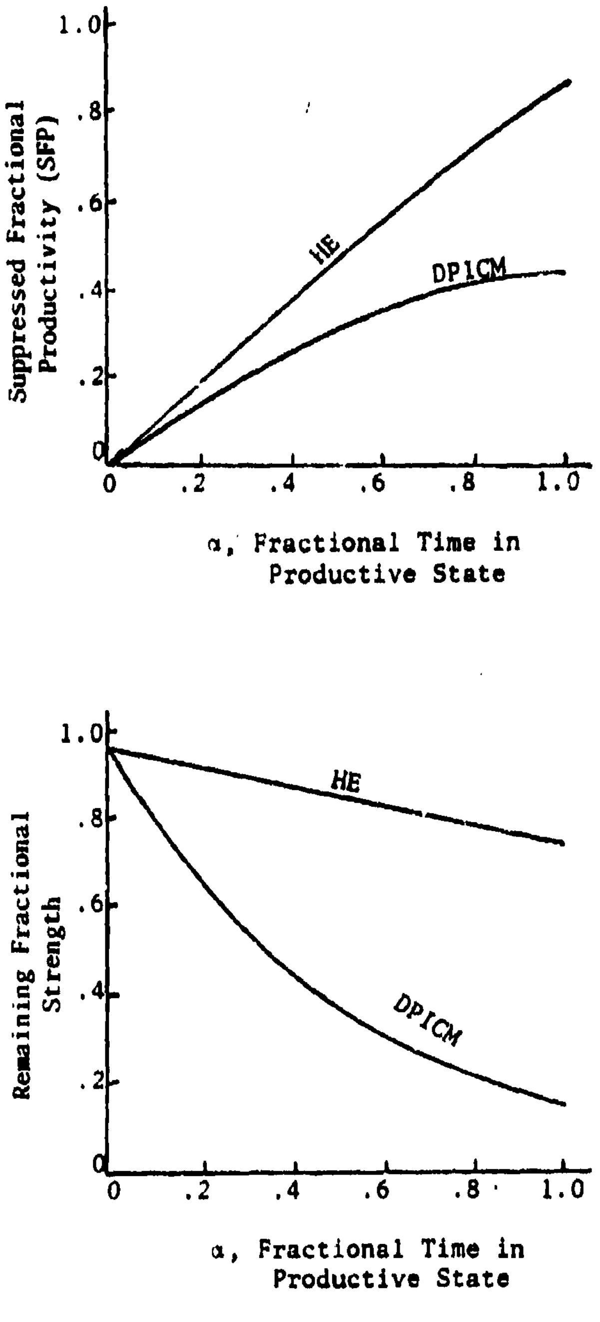

Figure I

Dependence on Duty Cycle Parameter, α

3.2 VACATING A POSITION UNDER FIRE

We have seen that the probability of surviving for time T under randomly timed volleys each of which yields a kill probability P is $\exp - (\lambda PT)$. If $P = P(t)$, it is easy to show that this expression becomes

$$q = \exp -\left(\lambda \int_0^T P(t)dt\right) \quad . \tag{11}$$

This is the situation when a unit vacates a position under fire. During the preparation for a move $P(t) = P_1$, but when leaving the position $P(t)$ decreases steadily as the unit moves away from the center of the target and approaches zero as the unit gains a safe distance. The relation between the geographical and temporal distribution of the kill probability P depends on how long the unit takes to prepare to move out (t_p) and how fast it moves once it gets under way (V).

Numerous calculations of the geographical distribution of P show that it looks much like a flat Gaussian distribution which becomes essentially zero at distances of about five hundred meters from the target center. A reasonab'e approximation for $P(t)$ is to take it as constant for $t \leq t_p$ and linearly decreasing to zero for $t_p \leq t \leq t_R + t_p$, where $t_R = R/V$, and R is the distance (500 m) from the target center at which the kill probability essentially vanishes. With V measured in kilometers per minute, then Equation (11) becomes

$$q = \exp - \lambda P_1 [t_p + 1/4V] \tag{12}$$

In Equation (12), q approximates the surviving fraction of a unit which vacates a position under fire, given that it was at full strength when the evacuation began. If the unit begins the evacuation at less than full strength, Equation (12) simply gives the proportional reduction.

3.3 ESTIMATING HOW LONG TO STAY IN THE PROTECTED STATE.

Suppose the victim unit elects to take cover in foxholes and stay there until the suppressive action terminates. It seems reasonable to postulate that when the victim unit has waited a long time without receiving any incoming rounds it should be safe to conclude that the suppression has lifted. But how long is "long"? The question can be rephrased in terms of the additional risk incurred by acting on the assumption that the suppression has indeed lifted.

Consider the case in which the suppressed unit is called upon to fire a mission of duration t_m. If the suppressive fire has not lifted, the probability of surviving for this length of time in the productive state is $e^{-\lambda P_1 t_m}$ and $e^{-\lambda P_2 t_m}$ in the protected state. If the suppressive action has terminated (and does not resume) the survival probability is unity in either state. Thus if the unit moves to the productive state and performs its mission, its probability of surviving for time t_m is

$$P = P_s e^{-\lambda P_1 t_m} + (1-P_s) \cdot 1 \quad , \tag{13}$$

and if it remains in the protected position, its probability of surviving for this time is

$$P' = P_s e^{-\lambda P_2 t_m} + (1-P_s) \cdot 1 \quad , \tag{14}$$

where P_s is the probability that the suppression has not lifted. The second course of action is safer but not productive. Let δ denote the additional risk due to chosing to fire the mission, i.e., $\delta = P' - P$.

In order to quantify δ, it is necessary to have estimates of λ and P_s; these can be obtained as follows: For λ, we can suppose that the victim

unit knows that it has been under suppression for a time T and in this time has received N suppressive volleys. (Even a subjective estimate of T and N should suffice.) Then,

$$\lambda \simeq N/T \tag{15}$$

Now imagine that the period T is followed by an observation period of duration t_o in which there is no incoming fire. The probability of this occurrence is (cf. Equation (1) with n = 0)

$$p_o = e^{-\lambda t_o} \tag{16}$$

If λt_o is large, p_o is small, i.e., it is unlikely that a period as long as t_o occurs in the Poisson process under consideration. We interpret this state of affairs as equivalent to the likelihood that the process is, in fact, continuing. I.e., for small p_o,

$$P_s \simeq p_o = e^{-\lambda t_o} \quad . \tag{17}$$

Then combining Equations (13) through (17), we find

$$\lambda t_o = \ln \frac{e^{-\lambda t_m P_2} - e^{-\lambda t_m P_1}}{\delta} \tag{18}$$

That is, given λ, t_m, P_1, and P_2 , we can solve for t_o, the time to wait with no incoming fire in order that an additional risk δ is incurred by deciding to move into the productive state and fire the mission.

Analysis shows that (λt_o) as a function of (λt_m) as expressed in Equation (18) has a very broad maximum; it is essentially constant for values of (λt_m) between 4 and 100, and this is the range of practical interest.

The magnitude of this constant maximum value of (λt_o), depends on δ and shows that the additional risk incurred by deciding to come out of the protected state and fire the mission is less than two per cent for values of (λt_o) greater than four. This conclusion leads to a useful result, namely an estimate of the time we may expect a suppressive action to be effective. The suppressed time is approximately the time taken to fire the suppressing volleys plus four interarrival times.* Victim units which remain suppressed for longer than this are behaving very conservatively while those which stay in the protected state much less than this will suffer a non-negligible amount of attrition.

$$T_s \simeq T + 4/\lambda \tag{19}$$

In Equation (19) T_s is the suppression time, T is the actual time duration of the suppressive fire, and λ^{-1} is the average interarrival time of randomly spaced suppressive volleys. No estimate of suppression time is completely accurate, of course, but the criterion developed here seems more reasonable than such bald assumptions as "Suppressed units will stay in foxholes for thirty minutes after the last volley impacts."

4.0 EXAMPLES OF SUPPRESSION UNDER RANDOM INTERVAL VOLLEYS

We can use the ideas outlined in the preceding sections to construct estimates of the consequences of various courses of action by either the suppressor or the suppressed. As a first example, consider suppression of a towed battery by DPICM volleys fired under a Poisson schedule with an average interarrival time of five minutes. The victim battery could fire one volley each minute if unopposed and at full strength. P_1 and P_2 are

* Provided, of course, that the suppressing volleys are too lethal to ignore.

taken from Table I, and it is assumed that the initial volley catches the victim in his unprotected condition. Figure 2 shows the time trends for various choices of the duty cycle parameter, α. It is clear that the unit which wishes to live to fight again should behave conservatively and defer firing its mission until the suppressive effort has lifted.

The next example further illustrates the possible consequences of alternate behaviors on the part of the suppressed unit. Suppose that the victim battery has an assigned mission of delivering 6,500 kg of projectiles as rapidly as possible. Just as it begins this effort, random suppressive fire initiates and lasts for fifteen minutes. The victim battery can either fire its mission and then vacate the position or shift its firing point half a kilometer and then fire its mission, or if it does not have armored weapons, men can take cover in foxholes till they are "sure" the suppression has lifted and then fire their mission. (In this last option, they use the $4/\lambda$ criterion of the previous section.) Table II gives the results of calculations based on the equations given in Section 3 and estimated performance parameters for the weapons involved.

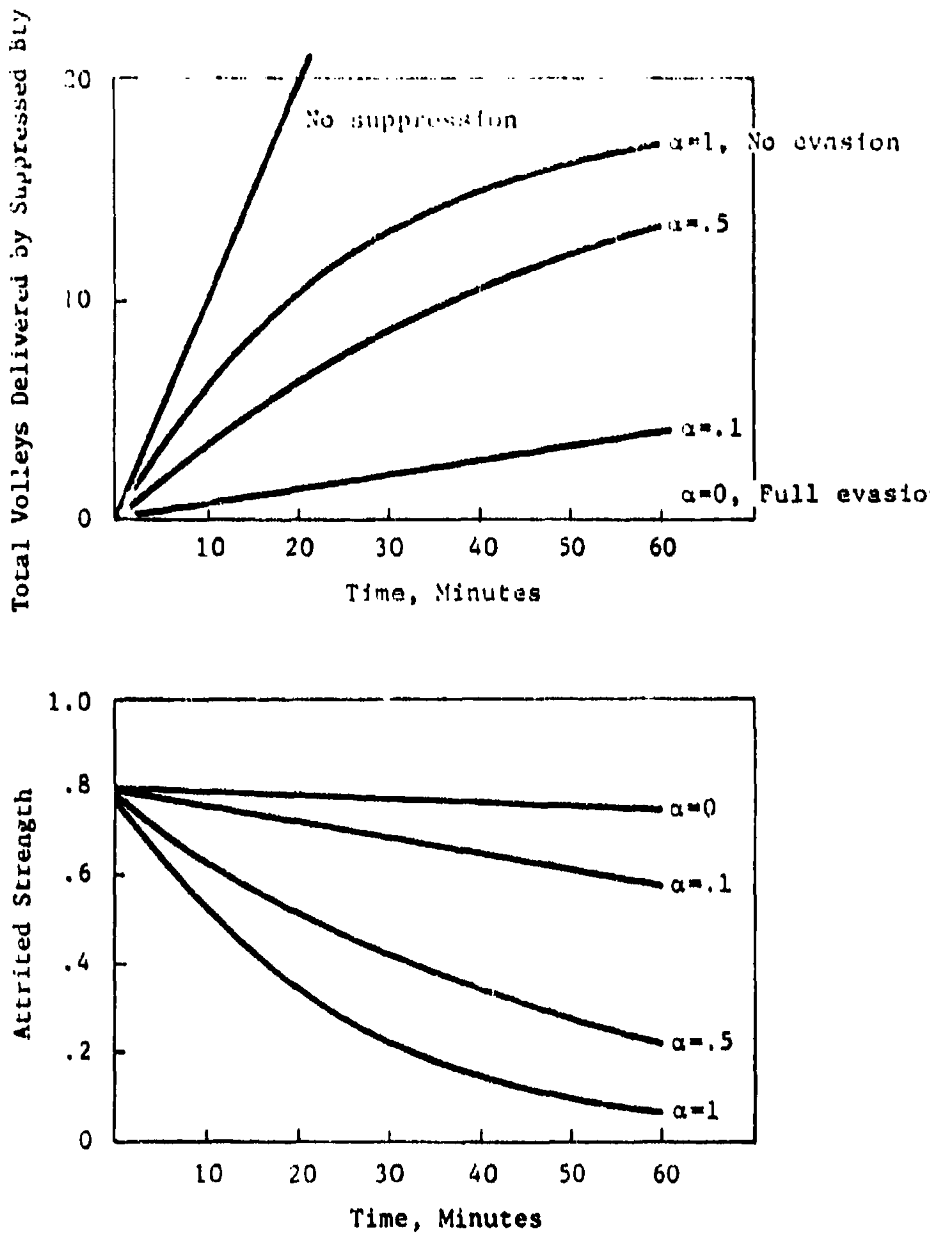

FIGURE 2
SUPPRESSED BATTERY PRODUCTIVITY AND ATTRITION

TABLE II

EFFECTS OF FIFTEEN-MINUTE SUPPRESSION MISSIONS

SUPPRESSOR[1]	VICTIM				
	WEAPON	MISSION[2]	RESPONSE	MISSION TIME	ATTRITION
M110 A-2 WITH DPICM	152 SP	25 VOLLEYS (10 MINS,	SCOOT THEN SHOOT SHOOT THEN SCOOT	14 MINS 11 MINS	1% 6%
M110 A-2 WITH DPICM	D-30 TOWED	50 VOLLEYS (14 MINS)	SCOOT THEN SHOOT SHOOT THEN SCOOT TAKE COVER	23 MINS 33 MINS 45 MINS	21% 63% 22%
M110 A-2 WITH HE	D-30 TOWED	50 VOLLEYS (14 MINS)	SCOOT THEN SHOOT SHOOT THEN SCOOT TAKE COVER	22 MINS 18 MINS 42 MINS	6% 22% 7%
152 WITH HE	M110 A-2	18 VOLLEYS (30 MINS)	SCOOT THEN SHOOT SHOOT THEN SCOOT TAKE COVER	41 MINS 53 MINS 52 MINS	14% 54% 7%

Notes: [1]The U.S. 8" weapons fire at an average rate of one volley per three minutes in these suppression missions. The Soviet 152 mm weapons fire at the more typical Soviet average rate of one volley per minute. Soviets use six-gun batteries, the M110 is a four-gun battery.

[2]In order to make the four cases shown in this table comparable, all victim missions consist of firing the same weight (6500 kg) of projectiles. Times shown in parenthesis would be required to execute this mission if the victims were not being suppressed.

Inspection of these results indicates that it is always advantageous for the Soviet units to interrupt their fire missions and relocate when they receive incoming. For this reason, this tactic has been attributed to Soviet artillery units in the combat analyses referred to in this paper. In this view, suppression really amounts to time lost due to forced relocation. The time required for Soviet batteries to reestablish a position and commence firing is minimal due to the availability of accurate land navigation systems in all of their batteries.

The trade-off between tactics is less clear for the U.S. 8" M110 A-2 weapons which are self-propelled but not armored. So long as the Soviet forces use HE ammunition in counterbattery fire and U.S. materiel is precious, the most advantageous tactic is to have the crews take cover until suppression lifts. If the M-110 series were modified to be as survivable as the 155 mm M-109 and the crew members given equivalent protection, it could shoot-then-scoot in 36 minutes with 18% attrition or scoot-then-shoot in 38 minutes with 5% attrition under the conditions of the example.

Two observations based on the above analysis and examples:

- As DPICM becomes generally available and single volley kill probabilities of about 20% are achievable against towed gun crews and about 2% against SP weapons, the primary suppressive effect on artillery batteries will be forced movement.
- As the best evasive tactic for the victim appears to be to leave the battery position quickly, much ammunition should not be spent in protracted suppression attempts unless there is information to the effect that the position has not been vacated.

5.0 SUPPRESSIVE EFFECTS IN COMBAT MODELING OF ALL-SP FORCES

The examples of the last section show pretty clearly that in a one-on-one situation there is considerable advantage of vacating a position when a battery begins to take serious incoming fire. This is particularly so for SP weapons, both because they are larger than towed pieces and hence more vulnerable to DPICM and because, being agile, it is easier for them to displace.

It is these forced moves of weapons which interfere with artillery productivity and in effect cause SP artillery to be suppressed. The magnitude of the effect and its impact on overall combat cannot be judged on the basis of one-on-one analysis; it is necessary to use more comprehensive analyses which represent the interactions of many military units and different types of equipment, and this of course requires computer simulation. One computer program useful in this respect is the Stochastic Artillery Combat Model (SCAM) which simulates the field artillery counterfire duel of a U.S. division with resolution to the level of individual weapons, crews, target acquisition, and C^3 assets. SCAM is two-sided and symmetrical with respect to the degree of detail and the interactive processes modeled for each side. Monte Carlo techniques are employed to reduce the performance statistics of the various battlefield systems to discrete events which the model tabulates. Systems are represented in terms of their technical performance characteristics, and a large number of decision parameters are available to represent tactical and doctrinal choices such as response to incoming fire, shoot-and-scoot procedures, etc. Small displacements which do not affect battlefield geometry are used to represent

forced evacuation of firing positions, and the time during which batteries are vulnerable while relocating as well as time to reestablish a fire position can be selected. Statistics pertaining to ammunition expenditure, attrition, and suppression, as well as many other factors are accumulated. Suppression is treated in terms of actual weapons effects and logical decisions are based on maximizing survivability or productivity depending on mission urgency at the time. The demand for target servicing indirect fire (TSIF) is an exogenous variable obtained from war gaming or general combat models, but the amount of TSIF delivered depends on weapon and munition availability, target list length, fire control time, mission priority, and numerous conditionals of system interaction. All in all, a reasonably accurate picture of artillery activities and effects is portrayed by this model. Numerous combat simulations have been run with SCAM to address various points, but most relevant here are some results which bear on the understanding of suppression.

As the primary object of counterfire is to reduce the amount of TSIF which the enemy artillery can supply, it is of interest to examine the factors which limit this. SCAM has been used to simulate the artillery battle in the SCORES European scenario which depicts a Soviet attack in the Fulda area. Principally, we have studied a 1986 technology scenario in which all Soviet cannon artillery units are represented as having self-propelled armored weapons. The first limit on the Soviet TSIF rate is imposed by the number of weapons, their technically achievable rates of fire, the Soviet doctrine on destructive effect per mission, and the C^2 time required per mission. Consideration of these factors leads to an

estimate of 55,000 rounds per hour as an upper limit on the amount of TSIF which could be provided by the Soviets. Ammunition resupply capabilities are estimated to be more constraining and would apparently limit Soviet TSIF to about 24,000 rounds per hour.

The remaining factors which limit TSIF depend on the scenario under consideration, but the situations investigated with SCAM appear to be both reasonable and representative. From analysis of Legal Mix V data we have established a rate of calls for TSIF based on considerations of target presentation rate and acquisition capabilities. If there were no U.S. counterfire, the Soviets would respond to these calls by providing some 11,000 rounds per hour of TSIF, a figure which is well within their technical and logistic capabilities, indicating a large capacity for absorbing punishment.

Assuming the availability of FIREFINDER, TACFIRE, GSRS, and enough DPICM, the effects of U.S. counterfire efforts in this scenario can be assessed. We find that the counterfire campaign is able to reduce the Soviet TSIF rate, by more than half, to 5,200 rounds per hour, while approximately forty Soviet weapons per hour are being killed. The result is somewhat surprising in view of the apparent over capacity of the Soviet system. Why is the Soviet force so inhibited? It should, in principle, be able to fire many more rounds if called on to do so.

In an attempt to understand the situation more fully, a special SCAM run was made which explores an artificial situation: The logic which forces victim battery movement in order to maximize survivability and productivity in the face of highly lethal incoming volleys was retained, but no kills were permitted. Thus, the pure suppressive effect was

separated from the pure attritive effect, with the enlightening result that the Soviet TSIF rate turned out to be 6,600 rounds per hour. Let us recapitulate these figures:

- With no counterfire, Soviets fired 11,000 TSIF rounds per hour.
- With counterfire without attrition, Soviets fired 6,600 TSIF rounds per hour.
- With attritive counterfire, Soviets fired 5,200 TSIF rounds per hour.

Thus, of the 5,800 rounds per hour reduction due to counterfire, 4,400 rounds per hour or 75% is ascribable to the (non-lethal) suppressive effect.

There is no doubt that forced movement is a very real and important contributor to fire support suppression. It must be emphasized, however, that the analysis is indeed scenario dependent, and it would be very misleading to take the results of the example just cited and use them out of context. In most SCAM simulations, we have required the Soviet cannon artillery to fire some 360 rounds of HE or 120 rounds of ICM per TSIF mission. These figures seem to be in accord with what the Soviets say they will fire to achieve their desired level of damage; such a doctrine does lead to long missions, however, and long missions get interrupted by efficient counterfire. Looking more deeply into the example above, we find that while in all cases the Soviets were responding to well over ninety per cent of their calls for TSIF, the average number of rounds per mission is only half of that desired when they are faced with counterfire. This, of course, is because their missions are interrupted by counterfire. Thus, if the counterfire system is not very rapid and responsive it will not be effective. Similarly, high rate of fire weapons such as rocket launchers which fire once and move out immediately are almost impossible

to suppress by returning fire on their launching positions. Other SCAM runs which model the Soviets as firing the same number of rounds per mission as would be indicated by U.S. doctrine, show that it is much more difficult to conduct effective counterfire in this circumstance because very few of their missions get interrupted. These results suggest that it may be possible to devise some optimal doctrines and technologies which minimize the effects of enemy suppressive efforts. Shoot-and-scoot tactics using ultra high rate of fire weapons appear very promising and offer an important difficult new problem for opposing target acquisition and counterfire weapon systems.

Acknowledgments

Dr. Max Oldham suggested the basic approach used here to describe the suppression of towed artillery crews. Dr. Neal Plotkin originally proposed the increased risk parameter as a way of approaching the question of how long such crews should stay in a protected, non-productive state. Mr. Richard Carpenter wrote the SCAM program and has been instrumental in its application to combat modeling problems. These and other colleagues at MITRE have contributed numerous insights in the course of many discussions.

APPENDIX F

Toward a Theory of Suppression

By

HERO Staff (Historical Evaluation and Research Organization, A Subsidiary of T.N. Dupuy Associates)

TOWARD A THEORY OF SUPPRESSION

A HERO STAFF PAPER

Any soldier who has been under hostile artillery fire or air bombardment is familiar with the experience of suppression, whether he has ever heard the term or not. The suppression he knew may have been brief --lasting only while he heard the whine of incoming shells, or the detonations of those shells or of aerial bombs. Or it may have lasted until all hostile aircraft were out of sight. Or--if the bombardment was particularly intense or prolonged--the feeling of terror and shock that even the bravest man feels under such circumstances may have lasted for some time after the last explosion faded from his ears. However long it lasted, his combat performance--energy, strength, initiative, skill, mobility--was degraded for that period of time.

In his article "The Shock Impact of Combined Arms Forces in World War II Amphibious Operations," published in the most recent issue of HISTORY, NUMBERS, AND WAR, the late S.L.A. Marshall mentioned a number of instances of suppression--including some in which the suppressive effect of gunfire and bombardment was very successful and some in which it was less so. The sergeant whose description of the effect of hostile Omaha Beach fire on his physical strength was quoted by Marshall--the man said he had barely been able to lift a machine-gun part he usually ran with--was obviously suppressed by the hostile fire, and the suppression effects lingered.

Thus, while it may not be easy for soldiers who have been suppressed by enemy fire and bombardment to define the term *suppression*, they well know what it means. It is an undeniable, and very important, phenomenon of combat.

For the purposes of this essay, and subject to possible revision as a result of further study and analysis, suppression can be defined as follows:

> Suppression is the degradation of hostile operational capabilities through the employment of military action which has psychological or physical effects impairing the combat performance of enemy forces and individuals who have not themselves been rendered casualties.

There is obviously an unmistakable, but so far not readily definable, relationship between casualties created by firepower and the suppressive effect of that firepower on those who either escape or evade the directly lethal effects of firepower. While it is possible to visualize other actions which can cause suppression, the action which most obviously and clearly results in suppression is that of directing lethal firepower at an enemy.

Suppression, Dispersion, Disruption

In searching for manifestations of the impact of suppression, we may look first at the increasing dispersion of military forces in combat as firepower weapons have become more and more lethal. There is no doubt that this relationship is real. The graph in Figure 1 shows visually the relationship between increasing lethality of weapons and steadily greater dispersion. As a result of this increasing dispersion, there has been a general decline in combat casualties over the course of modern history since the introduction of gunpowder weapons in the 15th and 16th centuries, although this decline has been neither steady nor consistent.

It is likely that the greatly increased dispersion that has occurred reflects not only a response to the direct effects of enhanced lethality (that is, the vulnerability of closely massed troops to such weapons as high-explosive shells), but reflects also the effects of suppression. Troops experiencing the suppressive physical and psychological effects of fire and bombardment are inevitably inhibited or degraded in performing such important tactical processes as maneuvering, but less so when they are deployed in open order rather than in mass. Thus dispersion is clearly a reactive manifestation of the effectiveness of suppression.

Other probable evidence of the significance of dispersion has been the increasing effort to provide additional protection to troops, through field fortifications, or armor, or mobility, or various combinations of these protective measures. Protected troops not only are more likely to survive fire and bombardment; they also feel safer, and thus inevitably, from what we know of the physical effects of fear, they perform better.

Still other, and more direct, manifestations of the suppression effect are such combat phenomena as the inability of troops to advance against effective, aimed defensive firepower, and the silencing of artillery formations by counterbattery fire. These failures are often out of proportion to actual casualties taken. The firepower that stops the attack or silences the hostile artillery may or may not inflict substantial casualties in the target formations. But even if the casualties are not significant,

the firepower has been effective, because it has rendered the opponents at least temporarily ineffective.

Although serious consideration has been, and is being, given to the question of representing suppression in modern models of combat, there has been no known effort to analyze suppression or its relationship to weapons lethality--either in connection with, or independently from, casualties--for the purpose of determining the morphology of suppression, or to measure its effects. However, HERO has performed two studies that could have considerable relevance to such analysis. One of these--"Historical Trends Related to Weapons Lethality"--was performed for the U.S. Army Combat Developments Command in 1965. The other--"Disruption in Combat"--was done for the U.S. Air Force, Studies and Analysis, General Purposes and Airlift Studies, in 1970.

Furthermore, in the development of the Quantified Judgment Method of Analysis of Historical Combat Data (QJMA), and its component Quantified Judgment Model (QJM), HERO has found it possible to quantify the disruptive effect of surprise, and also to relate normalized casualty-inflicting capabilities of military forces to combat effectiveness. Since there is an obvious relationship--even though not yet a readily definable one--between suppression, disruption, and casualty infliction, this past work offers considerable basis for confidence that comparable quantification is possible for the effects of suppression.

HERO has recently completed research for the Department of the Army on artillery rates of fire in recent wars. In the course of this work and in research for other studies HERO has repeatedly found references to the suppressive effect of artillery fire For instance, in a classic British Operations Research report of World War II we find the following words:

> "There is the question of numbers of shells as opposed to sheer weight --the age old argument in another form of field versus medium artillery. There are a lot of jobs where the heavier shells are essential, either because of their greater range or greater penetrative and explosive powers. But where lighter stuff can reach, and is capable of hurting the enemy, the evidence of these two reports seems to be that the thing that counts most of all is the number of bangs. Clearly one 100 pound shell is better than one 25 pounder one. It is on the other hand very questionable whether it is four times better."[1]

It is perhaps also significant that in its analysis of current Soviet artillery practices, HERO has noted a strong explicit emphasis on achieving "neutralization." The artillery fire methods of Soviet and some other armies combine periods of intense fire with intermissions during which there is continuing fire at a much lower rate. This method implicitly recognizes that the effect of suppression is achieved by some combination of massive shock action and uncertainty over a longer duration. It is clear from Soviet literature, furthermore, that the Soviets are attempting to quantify suppression; a more thorough study of Soviet military literature may give some hint as to their findings.

Tactical nuclear and chemical weapons would seem to be ideally suited for the achievement of suppression substantially in excess of the direct casualties they may inflict. By properly mixing the delivery of massive strikes and randomly timed fires it would appear to be possible to build on the already extreme psychological effects these weapons will produce.

On the other hand it is undoubtedly possible through proper training and indoctrination to reduce the effects of suppression by increasing the troops' ability to function under stress. There are many historical examples which show that a given amount of firepower had a more devastating effect on one force than on another. This of course is the reason armies attempt to make their training as realistic as possible. Yet no one has integrated numerical factors representing the ability of a force to withstand suppressive fire into an expression representing the disruptive effects of such fire, in order to develop a single model to explain and evaluate suppression.

Are There Laws of Combat?

The demonstrated interrelationship of firepower, mobility, and dispersion, and the potential relationship between the suppressive effects and the casualties of firepower, suggest the possibility of a theoretical interrelationship of basic combat measurement units similar to those that are found in mechanics, hydraulic theory, and electrical theory. In electrical theory, for instance, there are predictable, measurable relationships involving ohms of resistance, volts of electromotive force, amperes of current, coulombs of charge, henrys of inductance, farads of capacitance, watts of power, and joules of energy.

It is possible that some day someone may determine that there are laws governing combat that are comparable to Newton's Laws, or to Ohm's Law, and so forth. This possibility today seems to be far beyond "the state of the art" of military operations research or historical analysis of historical data, but results of HERO research suggest that historical combat data will permit empirical exploration of the general validity (or invalidity) of the following hypothesis:

Interrelationships among combat phenomena and processes can be ascertained in terms of three "firepower laws of combat":

1. Combat power is the product of firepower and all discernible environmental and operational variables of combat;

2. There is a dynamic relationship among firepower, mobility, and dispersion;

3. Firepower can be defined in terms of combat effectiveness, casualties, and suppression.

The first two of these "firepower laws of combat" have been substnatially demonstrated by HERO's QJM and other theoretical work, although the exact mathematical nature of the relationships cannot yet be stated.[2] The third "law" is a highly tentative hypothesis, which may be proven, or modified, in the process of historical research and analysis. If this hypothesis can be only partially or tentatively substantiated, however, it provides a means for better assessing the nature of suppression, and for determining means to measure it.

Are There Measures of Suppressive Effectiveness?

Another area of HERO's past research, related to the development of the QJMA, also seems relevant to the measurement of suppressive effects. HERO has demonstrated--rather conclusively we believe--that the outcome of a past combat engagement--who won and who lost, and how decisively--can be stated in meaningful quantitative terms by applying three measures of effectiveness to the performance of the opposing forces:

1. Relative mission accomplishment, or the extent to which the force accomplished its assigned or perceived mission during the engagement; this must be determined from an analysis of records by an objective historian--preferably by two or more historians since this assessment cannot avoid being subjective, no matter how objective the historians;

2. Spatial effectiveness, or the demonstrated ability of the force to gain or hold ground during the battle; this can be calculated by an empirically derived formula that considers the opposing force strengths, the quantified posture factors for each side, the battlefield depth of the opposing sides, and the distance gained (or lost) during the course of the engagement;

3. Casualty effectiveness, in which the personnel losses of the two sides are compared in another empirically derived formula, which also considers the starting strengths of both sides.

The values of these measures of effectiveness, separately or in combination, are obviously affected by all or most of the many variables of combat that influence combat outcomes. Not counting suppression as a combat variable (which it probably is), HERO has identified some 73 different kinds of combat variables which are believed to influence battlefield results.[3] If it can be found that the values of these measures of effectiveness vary to any degree in relationship to the weight or volume of suppressive firepower delivered by the opposing side--or delivered by one's own side--then it may be possible to find ways to measure the extent to which suppressive firepower--rather than normal or abnormal combinations of the other 73 variables of combat--has been effective in a particular engagement.

Some Questions for Researchers

The discussion up to this point suggests that there may be at least two different ways of assessing or measuring suppression: (1) as an element of three interrelated firepower laws of combat, and (2) by use of three combat outcome measures of effectiveness. The two approaches are not mutually exclusive, although it is obvious that either can be attempted without the other. Better, however, to try both--separately and (if possible) together. The extent to which these approaches can or should be related to each other should become evident fairly early in the research process.

Whatever the approach, some of the questions that will need to be answered are already apparent. Three of these appear to be basic:

1. How is suppression measured? Is it a function of weight of fire (in tons of steel and high explosive), or of volume of fire (in number of rounds), or of some combination of them?

2. What is the process of suppression? Is there a relationship between casualties and suppression?

3. What are the determinants of suppression?

In this process it may also be possible to obtain answers to a number of other questions, such as:

1. How does the amount of suppressive fire relate to assessments of total enemy power?

2. How does the spacing of suppressive fire relate to willingness to move forces and to the expectation of casualties?

3. How does perceived effectiveness of suppression relate to changes in attack plans?

4. To what degree does suppression effectiveness relate to communications disruption and to what degree does such disruption create a positive feedback loop?

5. How do amount and timing of suppressive fire relate to the individual and command estimates of overall power of the defender?

6. How do volume and density of suppressive firepower relate to estimation of one's own casualties?

Possibly the Soviets have discovered some way of confidently assessing the quantitative value of suppression. It is clear, however, that in the West there are today many questions and almost no answers about this important phenomenon of combat. We believe the above *tour d'horizon* suggests that if we can determine which questions are critical, and explore those further, we may finally be able not only to understand but even to measure suppression.

NOTES

1. Number 2 Operational Research Section report to the Army Council, "Operational Research in N.W. Europe" (London, n.d.), p. 185.

2. See, for instance, William G. Stewart, "Interaction of Firepower, Mobility, and Dispersion," *Military Review*, March 1960; and T.N. Dupuy and Janice B. Fain, "The Laws Governing Combat," *National Defense*, April 1975.

3. It should be made clear at this point that these are combat variables as seen by military historians, not by mathematicians; this list of 73 includes such hard numbers as weapons, and weapons characteristics, because they vary from one engagement to another; these are obviously not mathematical variables.

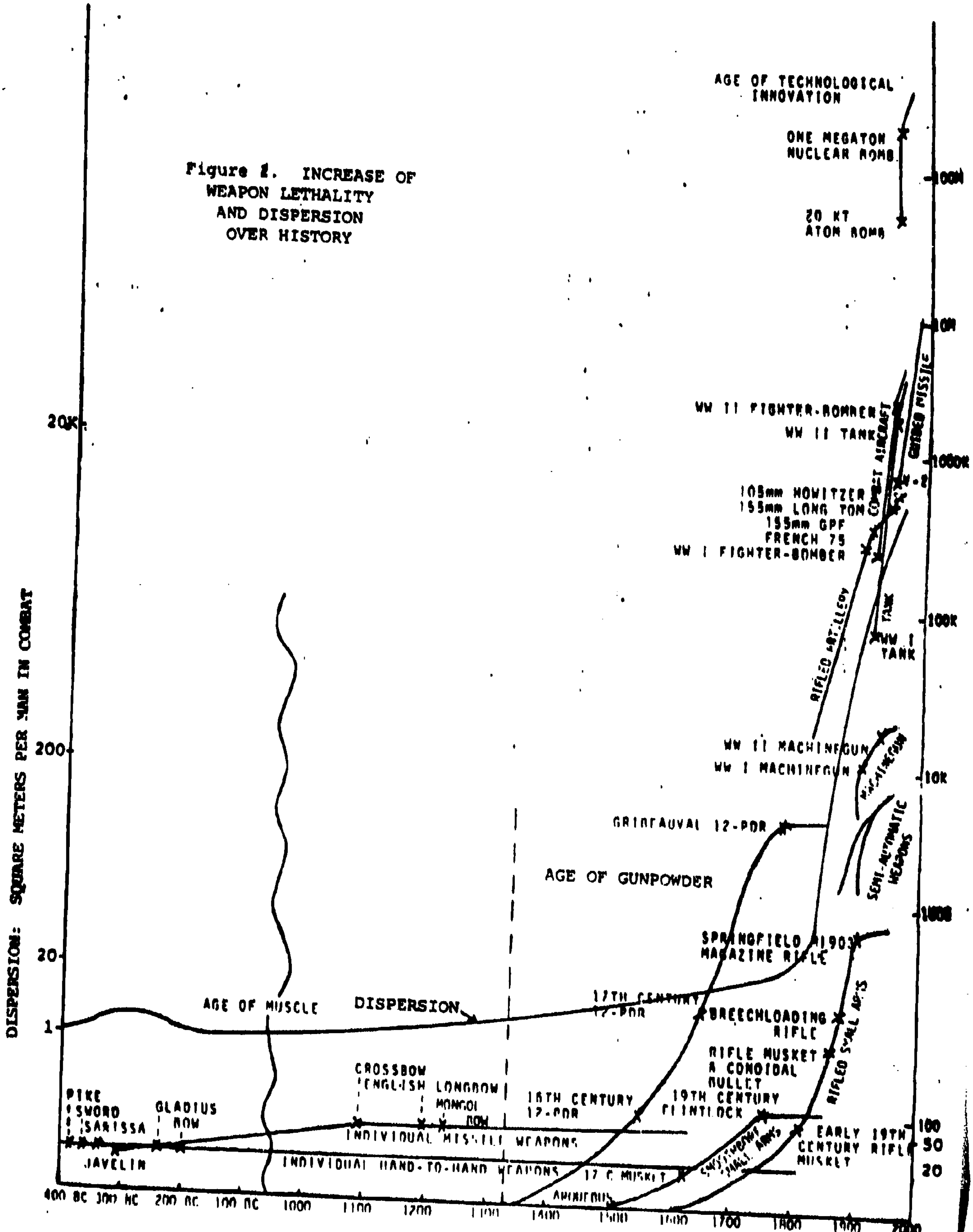
Figure 1. INCREASE OF WEAPON LETHALITY AND DISPERSION OVER HISTORY
AGE OF TECHNOLOGICAL INNOVATION
ONE MEGATON NUCLEAR BOMB
20 KT ATOM BOMB
WW II FIGHTER-BOMBER
WW II TANK
105mm HOWITZER
155mm LONG TOM
155mm GPF
FRENCH 75
WW I FIGHTER-BOMBER
GUIDED MISSILE
RIFLED ARTILLERY
TANK
WW I TANK
WW II MACHINEGUN
WW I MACHINEGUN
MACHINEGUN
SEMI-AUTOMATIC WEAPONS
GRIBEAUVAL 12-PDR
AGE OF GUNPOWDER
SPRINGFIELD M1903 MAGAZINE RIFLE
17TH CENTURY 12-PDR
BREECHLOADING RIFLE
RIFLE MUSKET & CONOIDAL BULLET
RIFLED SMALL ARMS
16TH CENTURY 12-PDR
19TH CENTURY FLINTLOCK
EARLY 19TH CENTURY RIFLE MUSKET
17 C MUSKET
SMOOTHBORE SMALL ARMS
ARQUEBUS
AGE OF MUSCLE
DISPERSION
PIKE
SWORD
SARISSA
JAVELIN
GLADIUS
BOW
CROSSBOW
ENGLISH LONGBOW
MONGOL BOW
INDIVIDUAL MISSILE WEAPONS
INDIVIDUAL HAND-TO-HAND WEAPONS
DISPERSION: SQUARE METERS PER MAN IN COMBAT
1
20
200
20K
20
50
100
1000
10K
100K
1000K
10M
100M
400 BC
300 BC
200 BC
100 BC
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000

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WEAPONS EFFECTIVENESS AND SUPPRESSIVE FIRE

Mr. George M. Gividen

US Army Research Institute

PURPOSE:

The purpose of this presentation is four fold:

First, to summarize previous research in the area of suppressive fire as a component of weapons effectiveness.

Second, to discuss several attempts to develop valid models which would define the relationship between weapons characteristics and effectiveness in suppression.

Third, to identify some of the contributions of suppressive fire studies to weapon systems design and procurement decisions.

Fourth, to clarify the primary issues relating to proposed research in the suppressive fire area.

The primary emphasis will be on small arms weapons systems. The phenomena of suppression is complex; all too often those who would perform research in this area have committed the error of oversimplification, failing to realize that suppression is a function of literally hundreds of different variables, of which weapons characteristics represent only a small number.

The effectiveness of any weapons systems is a function of its performance in each of the roles that it will be expected to fulfill. The primary function of weapons is to decrease the effectiveness of the enemy. This may be done by eliminating these enemy forces or by preventing them in other ways from accomplishing their objectives. Weapons may be effective by physically incapacitating the enemy or by psychologically reducing his effectiveness. Any research program to improve weapons effectiveness must, therefore, concern itself with first identifying a set of measures of effectiveness, and second, with identifying objective relationships between these effectiveness measures and weapons characteristics.

Previous studies have been consistent in identifying five major interdependent measures of effectiveness for most weapons systems:

Hit capability
Suppression capability
Lethality
Reliability
Sustainability

All are time related, and each is a function of the others. Thus, the weapon with a high single round hit probability may not have as great a

hit capability in combat as a less accurate weapon which can put out a much greater volume of fire within the same time span.

In this respect, Combat Developments Command Experimentation Command (USACDEC) tests showed that soldiers equipped with 7.62mm M14 rifles consistently hit more long range targets per round of ammunition fired than did M16 firers. However, M16 firers (firing 5.56 mm rounds that weighed only half as much) scored significantly more hits at all ranges per pound of ammunition fired. M16 hits were also secured more quickly than M14 hits, which means that M16 firers would have been subjected to a shortened duration of return fire from the enemy.

The M16 firers were also able to sustain their fire effects for a longer period of time due to the lightness of the weapon and ammunition which permitted more rounds of ammunition to be carried. Within the basic weapon system weight of 17 pounds prescribed for the rifleman, the M14 soldier carries only 100 rounds as opposed to 300 for the soldier armed with the M16. If time intervals of fire were equated, and rates of fire were identical, the M16 firers would have been able to sustain their effects for three times as long as the M14 rifleman.

On the other hand, a weapon with an extremely high single round hit probability may be relatively ineffective because of low lethality or because its reliability is so low that it is unable to fire many rounds because of malfunctions. In like manner, the suppressive effects that a weapon produces may be diminished by high malfunction rates or by inability to transport the quantities of ammunition necessary for sustaining fire. The suppressive value of small arms weapons systems is also diminished when the weapon's projectiles are not perceived as being very lethal; and when projectiles are not perceived as being threatening, suppression will not be effected.

Mobility of weapons is a component of sustainability in that the amount of ammunition a soldier can carry is diminished as the weight of the weapon increases. As sustainability of a weapon is increased through increasing the ammunition load, mobility is correspondingly made more difficult and decreased.

THE NATURE OF SMALL ARMS SUPPRESSION RESEARCH

Although all of these five measures of effectiveness are components of an integrated system of effectiveness, each may be considered and examined as a subsystem. In this respect, hit probabilities, lethality, reliability and sustainability have been the subject of far more detailed research than suppression. This is attributed to the fact that each of the first four is more easily studied quantitatively from the point of view of the physical sciences.

For example, rifle hit probabilities may be physically measured in terms of hits on targets as a function of specific measurable ranges and number of rounds fired, while reliability is basically a matter of compiling numbers, types and causes of malfunctions over a period of the weapon life cycle. Sustainability of a weapon system may be studied as a function of rates of fire, basic loads of ammunition, logistics

and similar numerical factors. Lethality is a more complex measure but extensive data have been made available from gelatin block experiments, penetration studies, animal studies, and studies of human wounds in combat to include extensive medically based classification schema.

On the other hand, suppression deals with numerous psychological factors. There is, of course, "permanent suppression" from physical factors -- the soldier who is severely wounded or killed becomes "permanently suppressed" -- but studies in this area fall under the "hit capability" and "lethality" categories previously mentioned. Psychological suppression from small arms fire is a more complex phenomenon. Unlike hit capability and other effectiveness measures, suppression or its causes cannot be measured directly in most cases. Since phenomena within the human mind are of concern, casualty must sometimes be inferred or indirectly established.

Furthermore, it is not possible to study suppression primarily as a system of discrete numbers. In researching hit capability (to include hit probabilities), a target is either hit or it is not. When considering lethality, the reaction of a gelatin block to the penetration of the bullet may be recorded and measured by high speed photography. But such finite physical measurements are usually not possible when one examines suppression.

A period of slightly reduced effectiveness which lasts only several seconds may constitute suppression in one instance while in another case suppression may consist of an immobilizing terror and shock that results in a prolonged total incapacitation requiring psychiatric treatment. Furthermore, the reaction in the same soldier to the same stimuli and cues may be vastly different from one time to the next. Suppression is also influenced by a much greater variety of extraneous factors than the other measures of small arms effectiveness. Training, leadership, morale - even religious beliefs - are only a few of the many factors that determine the degree of suppression that may be effected on any one individual at any given time. Suppression, therefore, becomes the most complex component of weapon systems combat effectiveness studies.

DEFINITION OF SUPPRESSION

Most previous suppression research has been concerned only with suppression by small arms fire. On the other hand, small arms fire is usually only one of many types of weapons fire contributing to suppression at any given time. Even in the final stages of an assault when only small arms are being used, the suppression that occurs may be, in reality, only a continuation of the suppression <u>effects</u> that occurred as a result of heavy preparatory tank, mortar, and/or artillery fire. Although there are many and varied definitions, suppression is operationally defined here as:

> "A state of relative ineffectiveness or incapacitation of the individual soldier which is a function of psychological factors, and which is either initiated or maintained by a perceived threat from weapons fire."

Within a psychological framework and in the language of the psychologist, suppression is defined as:

> "The resolution of an approach-avoidance conflict in an individual by taking the avoidance response."

DIMENSIONS OF SUPPRESSION

Previous research studies indicate that there are five primary dimensions of suppression and that it is important to understand these dimensions prior to conducting any investigation of suppression for the weapons characteristics most desirable in one case may not be applicable in another. These five dimensions are:

- Reasoned (Rational) Suppression versus Unreasoned (Irrational) Suppression.

In reasoned suppression the soldier rationally analyzes the situation and mentally calculates the probabilities for mission success and survival. The soldier who keeps his head down and cooly waits until the enemy has exhausted much of his ammunition before resuming the assault has had his effectiveness temporarily reduced and, therefore, has been suppressed. This constitutes reasoned suppression. On the other hand, the soldier who reacts out of panic or psychological fear without consciously thinking or considering the real nature of the threat or long term effects is reacting without reason, which constitutes unreasoned (irrational) suppression.

- Area Suppression versus Point Suppression.

The suppression resulting from mortar fire or from the classic distribution of machine gun fire between two reference points is an example of area suppression. The soldier who has been suppressed as an individual by sniper fire or by an enemy machinegun specifically aimed at his location has been incapacitated by point suppression. The weapon which is best for area suppression may be relatively unsatisfactory in a point suppression role.

- Defensive Suppression versus Offensive Suppression.

Some of the weapons characteristics which make the greatest contributions to effectiveness of suppression in offensive situations may be different from those most desired in the average defensive engagement. One study, for example, indicates that the infantry weapon with the greatest suppressive effect against assaulting enemy troops is the machinegun, whereas the weapon providing the greatest suppression against emplaced defending enemy troops is the mortar. The recoilless rifle is perceived as more effective than the automatic rifle against defending troops whereas the reverse is true against assaulting troops.

- Lethal Suppression versus Denial Suppression.

Suppressive fires may be used against an area or positions that the enemy is known to occupy. In these instances, the objective is to neutralize the enemy by preventing him from moving or using his

weapons or by killing him if he attempts to. This is known as lethal suppression, whether the "suppression" occurs by physically killing and disabling the enemy, or whether it occurs as a result of a psychological fear which causes the enemy to remain immobile and not use his weapons. Denial suppression is used against areas unoccupied by the enemy and is used to deny them access to that area or position. Continuous bursts of machinegun fire fired down a stretch of road or across the entrance to a bridge are examples of denial suppression. The same psychological factors that prevent a soldier from sticking his head out of his foxhole to fire his weapon also keep him from venturing up the slope of a hill through interlocking machinegun fires or exploding grenades.

- Direct Fire Suppression versus Indirect Fire Suppression.

This dimension, of course, is a classic one. In the case of small arms, grenade launchers and hand grenades are considered to be the only effective weapons for use in the indirect role while rifles, automatic rifles, machineguns and grenade launchers may all be used for direct fire.

DEGREES OF SUPPRESSION

As already discussed briefly, suppression is a state which may last for only a few seconds or it may "permanently" incapacitate a soldier just as effectively as a bullet, to the extent that the soldier must be evacuated for psychiatric care. S. L. A. Marshall's description of suppressed American soldiers on Omaha Beach on the afternoon of D-Day, June 6, 1944, is an excellent example of the latter:

> "They lay there motionless and staring into space. They were so thoroughly shocked that they had no consciousness of what went on. Many had forgotten they had firearms to use. Others who had lost their firearms didn't seem to know that there were weapons lying all around them. Some could not hold a weapon after it was forced into their hands...Their nerves were spent and nothing could be done about them."

At the other end of the continuum would be a hypothetical soldier who is not subject to suppression, who does not duck or in any way adjust his actions as a result of being suddenly brought under fire, and, who, because of his foolishness, dies! The majority of historical instances of suppression lie somewhere between these two extremes.

Many researchers in the past, particularly those who have not experienced infantry combat or who have based their studies solely on after-action interviews, have been unsuccessful because they did not understand the desired objective of suppressive fire or its full psychological implications. The objective of suppressive fires is not just to neutralize or incapacitate the enemy during the time he is being subjected to suppressive fire. Effective suppressive fire (of the "Lethal Suppression" type) is such that the enemy remains incapacitated for a period of time after the fires are lifted. This period of psychological shock should ideally be of sufficient duration

to permit friendly forces to fully exploit their advantage, e.g., move onto the enemy position in an assault and capture or kill the stunned enemy in their emplacements without receiving return fire. The length of this post-suppressive fire incapacitation will vary from a few seconds to minutes to hours depending upon many factors, some of which will be discussed later.

It is extremely difficult to collect valid data on these post-suppressive fire investigations through the use of interviews and questionnaire techniques. In most cases there is no stigma attached to having been pinned down or suppressed in a fire fight. In fact, every infantryman who has served in combat for any length of time has been "suppressed" many times. But for a soldier to admit post-suppressive fire incapacitation (that he did not fire his weapon or that he remained temporarily in a state of shock in the bottom of his foxhole after enemy fire was lifted) is something entirely different, for the label and social stigma of cowardice is attached to such conduct. The most feasible approaches for collecting information in this area are interviews where the responder is asked to describe the conduct and actions of his fellow unit members, or when anonymous questionnaires are used in a group setting.

Point Suppressive Fire may also be quite effective. Military history is replete with examples of lone snipers who were able to quite effectively suppress or delay the advance of entire units.

The degree of suppression inflicted upon a unit may be measured in two categories. The first involves the degree of incapacitation suffered by individuals, whereas the second involves the total number of personnel affected within the unit. Theoretically, the same loss of unit effectiveness might result from all unit members being slightly incapacitated, as from a fraction of the members being severely affected.

Suppression, therefore, occurs on a continuum ranging from incapacitation requiring evacuation to no incapacitation at all. It may seriously affect only several members of a unit at any given time, while at other times all members of the unit may be pinned down simultaneously.

FACTORS AFFECTING SUPPRESSION

Although most research projects are primarily concerned with determining objective relationships between weapon systems fire characteristics and effectiveness in suppressive fire, we cannot ignore all of the other factors that contribute to suppression in any given situation. We have already discussed the five primary dimensions of suppression and emphasized that those factors which most influence suppression in one situation may have relatively little effect in another.

Litton's Defense Sciences Laboratories, during the course of extensive work in the small arms area, has obtained and researched more than 1200 documents and combat films which initial research indicated were related to suppression. As a result, much of the background research work required to effectively initiate a detailed study of suppression

has already been accomplished, and many of the hypothesized factors and weapons characteristics related to suppression have already been identified. In addition, literally thousands of combat veterans (Viet Cong, NVA, Australian, Korean, South Vietnamese and U.S.) have been interviewed in depth and administered questionnaires relating to suppression. Field tests have also been conducted.

These research efforts and analyses of previous research reports, after action reports, combat films, questionnaire results, and other related material, have identified literally hundreds of factors affecting suppression. Some make substantial contributions while the effects of others are negligible in most situations. Many are specific subsets of a larger more general factor. A sample of some of these factors that have been identified ar listed below. Weapons fire characteristics (often overlapping) are listed first, followed by a short list of other factors which interact to determine the degree of suppression.

SAMPLE OF WEAPONS FIRE CHARACTERISTICS

Volume of fire per unit time
Cyclic rate per burst
Acoustic signature (volume)
Acoustic tone
Accuracy of fire
Perceived lethality of projectiles
Distance of passing or impacting projectiles from the soldier
Manner of distribution of fire
Coordination of fire with suppressive fire from other types of weapons
Weapon's basic load
Visual cues
Uniqueness of sound (e.g., ability of enemy to consistently identify the sound with a particular weapon)
Actual lethality of projectiles
Signature cues at the weapon (e.g., muzzle blast)
Inflight visibility of projectiles (e.g., tracer)
Impact signature (e.g., debris or dust thrown up by impacting rounds)
Time to reload
Reliability

SAMPLE OF OTHER FACTORS

Experience under fire
Leadership of the unit
Fatigue
Availability of cover and concealment
Religious beliefs
Mission type
Distance from enemy
Proximity of soldier to automatic weapon (those close to friendly machineguns fire more and are suppressed less)

Reaction time of target
Previous training
Weather
Availability of routes of withdrawal
Time remaining before rotation
Time of day (night)
Morale
Number of casualties being received by unit while under fire
Proximity to unit leader
Ability to see and be seen by other soldiers
Firer/target density

These factors represent only a sample of the total possible factors influencing the initiation, maintenance and post-suppression fire effects of suppression.

ATTEMPTS TO MODEL SUPPRESSION
Work by Kinney, Swann, and others at the Naval Weapons Center at China Lake, California, represents one approach to the modelling of suppresion. Their work has been primarily in the area of fragmentation weapons used by aircraft to suppress infantrymen. They have developed an analytic model for computing suppression effects which uses existing warhead lethality or P_K descriptions. The model has been used for computing quantitative estimates of the suppression capability of the AH-IJ helicopter weapon system. However, these quantitative estimates have no real meaning except in conjunction with comparisons of similar estimates from other weapons systems. One may also not be willing to accept some of their definitions or assumptions. Their model, for example, is based upon the assumption that the higher the lethality of a weapon, the longer it will take to recover from suppression by that weapon. Yet we know of no evidence in the literature to support this. In fact we hypothesize, for example, that the frequency and number of <u>low</u> lethality weapons rounds may be such that longer periods of suppression will result than for fewer rounds of greater lethality. This study does not consider the weight of rounds, which, of course, may be interjected later.

The significance of projected size and weight warrants mention at this time. If we are not careful to consider weight and size we fall into the trap of concluding that because the ammunition of weapons system A is more suppressive than the ammunition of weapons system B, then system A must also be more suppressive than system B! This, of course, is not true. For example, the M14 round makes more noise passing overhead than the M16. It yields a considerably larger visual signature upon impact and under some circumstances is more lethal. According to all rational criteria it may be considered at least as suppressive a round as the M16. But, we have to consider, as mentioned earlier, that the M16 round weighs only half as much as the M14 round, and because of lighter weapon weight, 300 M16 rounds can be carried within the 17 pound M16 weapons system load - as opposed to only 100 M14 rounds within the 17 pound M14 basic weapon system load. Furthermore, most soldiers perceive that if they are hit in the head with an M16 bullet they are going to be just as dead as if hit by an M14.

It is obvious then that the M16, which can put out 3 times as many rounds per unit of time per basic load as the M14, is considerably more suppressive than the M14. In fact, since the hit probabilities and P_K values (at expected ranges of engagement) of the two weapons were not far apart, the suppressive superiority of the M16 over the M14 was one of the primary reasons it was adopted. In like manner, it makes no sense to say that 40mm grenade launcher are better suppressive fire weapons than M16 rifles. Quite the contrary, many feel that 20 M16 rounds spaced out over, say a 1 minute time period, will have far greater suppressive effect during that minute than one 40mm grenade which weighs the same as 20 M16 rounds.

The models presented in the China Lake study are applicable only to weapons with high-explosive fragmenting warheads. Weapons or projectiles with non-explosive warheads such as rifles, and weapons with fuel-air explosive and flame warheads cannot be analyzed with these models. The study itself, points out that there is still much that needs to be done. For example, major modeling concepts and input parameters have not been validated, and the model does not provide for anticipatory suppressive behavior which, of course, is one of the primary reasons for attempting to effect suppression.

As mentioned earlier, Litton's Defense Sciences Laboratory conducted extensive literature surveys, interviews, and questionnaire administration and conducted five field experiments in an attempt to quantify relationships between small arms characteristics and suppression. The principle findings of this research in which hundreds of variables were considered were, first, that the major factors producing suppression were loudness of passing rounds, the proximity and number of passing rounds and the signatures associated with rounds impacting. Within the limits of the distances employed in the study, suppression was shown to decrease in a linear fashion with increasing lateral miss distances of incoming projectiles. Within the limits of number of rounds employed in this study, suppression was shown to increase linearly with increase in volume of fire. Within the limits of the projectiles employed, suppression was shown to increase in a linear fashion with increase in the perceived loudness of passing projectiles. It was also found, as would be expected, that a combination of both auditory and visual signatures from near misses was more suppressive than auditory signature alone. Finally, a set of recommendations for design considerations to enhance the suppressive capability of small arms weapons was developed. The study also concluded that a multiple regression model can be employed to predict the degree to which a soldier would be suppressed by a given weapon under various circumstances. To predict suppression in combat, the model must include such factors as the characteristics of the weapon and situational variables, and must take into consideration the experience and psychological make up of the individual. Perceived dangerousness of projectiles was an important factor among those leading to an individuals' being suppressed. The actual P_K value of a round was not shown to be directly related to its perceived dangerousness, an assumption that other studies often make. We cannot discuss details or specific examples because this information is classified, but we can say that some of the highest lethality projectiles had the lowest suppression

effects. Some of the loudest noise projectiles (40mm) also have relatively low lethality while other have high lethality. Where the impact of rounds was visible, the visual signature had more suppressive effect than the acoustic signature. The major weapon characteristics which should be entered into the model are class of weapon, projectile caliber, projectile velocity, cyclic rate of fire and the weapons dispersion. In another Litton study, this time of suppressive effects of supporting weapons, no quantitative data on suppressive effects was found. Probably the most important finding of this research was, and I quote, "The combat suppression phenomenon is too complex to be amenable to references that rely on laboratory or experimental findings...suppressive behavior is high variable." Litton, however, did develop a model (to be used in conjunction with other research) that requires expected fraction of casualties and a human factors coefficient as inputs, but recommends again that the void in quantitative data on suppressive effects should be filled by analysis of combat after-action reports that include an orientation towards suppressive behavior rather than any experimentation. A method for calculating suppression level and a probabilistic model of suppression are provided in the Litton report. The model allows for Monte Carlo runs, expected value determination, parametric studies, and sensitivity analyses.

As of this time little direct use has been made of the results of suppression research. The Litton support fire model has been used in conjunction with the Bonder Independent Unit Action Model in an evaluation of the Bushmaster. At Fort Benning suppression has been incorporated into the Army Small Arms Requirements Study Small Unit Engagement Model. A Litton model was used here and the Delphi technique was used to collect input data. One of the first real uses of suppression research data was in the Small Arms Weapons System (or SAWS) study of 1965 and 1966 which resulted in the junking of the M14 rifle and adoption of the M16. The M14 was a larger caliber rifle with higher hit probabilities per round, especially at long ranges. However, it was determined by CDEC that suppression must also be measured. The other agencies involved in SAWS did not consider suppression and all recommended that the then TOE M14 be retained. CDEC, however, on the basis of the superior suppressive fire and sustainability characteristics of the M16 recommended it be adopted and the M14 discontinued. DA reviewed all of the SAWS reports and recommendations, accepted CDEC's, rejected the others, and the M16 became the new US Army rifle. In this case, CDEC's research consisted primarily of setting up acoustic miss distance indicators at the center of realistically deployed and camouflaged targets in six different tactical situations. Squads of troops equipped with different small arms systems attacked or defended against these operational arrays. The data was collected by computer and later incorporated into a simplistic model which gave suppressive capabilities of the weapons one-third of the total effectiveness weight. It was found in the field tests that soldiers consistently were able to put significantly more M16 rounds within given distances of the target per unit of time and per equivalent weight basic load than were M14 firers, even at longer ranges.

SUMMARY

Today, we have attempted to detail the necessity of considering suppressive fire characteristics in weapons system design and evaluation. We have summarized previous research in the area and have discussed contributions of past suppression research and have looked at attempts to model suppression.

Suppression research is a complex area of study requiring multidisciplinary talents to include primarily those of the soldier and the psychologist. A considerable body of literature relating to the subject is currently available, however, some of the most pressing questions in the area have not been answered. Indeed, some experienced suppression researchers maintain that some of these questions may be unanswerable.

RECAPITULATION

As a result of the symposium the ground work was laid for a coherent approach to achieving a unified method for studying suppression. After a thorough review of this report, an action plan will be written to follow through on the ideas generated during the work sessions.